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Example Modeling to Illustrate SIP (State Implementation Plan) Development for the PM(10) NAAQS (National Ambient Air Quality Standards)

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16. ABSTRACT

This document provides an illustration of the use of modeling techniques for SIP development for the PM_{10} NAAQS. Available dispersion and receptor modeling techniques are applied and their results are compared. Analyses applicable to both the annual and 24-hour PM_{10} NAAQS are demonstrated. The application of models in control strategy development is described. The examples provided include an urban area problem and a problem caused by an industrial source with fugitive dust.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
PM_{10} PM_{10} NAAQS PM_{10} SIP Development Dispersion Modeling Receptor Modeling Particulate Matter Standard		

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1.0 INTRODUCTION

EPA has revised the 24-hour and annual primary National Ambient Air Quality Standards (NAAQS) for particulate matter. The ambient monitoring reference method, form and concentration levels for the standards were changed. The former standards were based on total suspended particulate matter (TSP), as measured by the high-volume sampler. The revised standards are based on PM_{10}, a measure which includes only that material collected by a sampler with a 50 percent collection efficiency at an aerodynamic diameter of 10 µm.

The revised standards are of a statistical form, by contrast to the previous deterministic form, and are listed in Table 1-1. For example, the revised 24-hour standard allows up to three exceedances over a three year period, while the former 24-hour TSP standard allowed only one exceedance per year. Similarly, the revised annual standard applies to the average of three consecutive annual averages, instead of applying to annual averages of individual years. Furthermore, the revised annual standard is expressed as an arithmetic average, rather than a geometric mean.

Under the Clean Air Act (Section 110(a)), State Implementation Plans (SIPs) are required for the purpose of attaining and maintaining NAAQS in all areas of each State. As a result, each State is now required to revise its TSP SIP to address PM_{10} instead. In recognition of the wide range in air quality likely to be encountered within each State, EPA has established different PM_{10} SIP requirements for each of three groups of areas: Group I: areas shown to be, or have a high probability of, nonattainment; Group II: areas where attainment is uncertain; and Group III: areas shown to be, or have a high probability of, attainment (U.S. EPA, 1986a). In Group I areas, modeling analyses will be required to apportion source contributions

TABLE 1-1

PM_{10} AIR QUALITY STANDARDS

National Ambient Air Quality Standard	New Form and Numerical Value
24-Hour (Primary)	PM_{10}: 150 μg/m^3 Expected number of exceedances less than or equal to one per year.
24-Hour (Secondary)	Same as primary
Annual (Primary)	PM_{10}: 50 μg/m^3 Expected annual arithmetic average

and to estimate current and future concentrations (PM$_{10}$ SIP Development Guideline, U.S. EPA, 1987a). Where existing controls are not adequate, nonattainment will be indicated and revised control strategies must be developed.

In general, the activities States will perform to attain PM$_{10}$ NAAQS are not expected to differ radically from past activities directed towards attaining TSP NAAQS. However, several changes associated with the PM$_{10}$ NAAQS necessitate revisions in the specifics of particulate matter control strategy development. These include:

- The change in size range from TSP to PM$_{10}$
- The statistical form given to the PM$_{10}$ NAAQS
- The lack of an extensive historical PM$_{10}$ data base
- Use of receptor modeling as a complementary method to dispersion modeling

An effect of these changes is an increase in the complexity of some of the tasks required for SIP development. To assist States with these tasks, this document provides a structured framework for PM$_{10}$ SIP preparation and illustrative examples of the PM$_{10}$ SIP development process.

1.1 Technical Overview

The development of control strategies to attain and maintain PM$_{10}$ air quality standards requires reliable methods for estimating the following:

- Source contributions to observed air quality
- Air quality at locations where monitoring data are not available
- Changes in air quality which would result from changes in emissions

Methodologies for obtaining these estimates fall broadly into two categories: 1) dispersion models and 2) receptor models. Dispersion models are designed to predict ambient air quality and/or define the relationships between source emissions and ambient concentrations. Receptor models are designed to apportion source contributions based on a mass balance analysis of source and ambient particle composition.

A systematic approach for applying dispersion and receptor models is shown in Figure 1-1 which represents PM_{10} SIP development as a four step procedure: 1) determine the SIP revision requirements; 2) historical data base evaluation and model selection; 3) model performance evaluations; and 4) control strategy evaluations. The procedure emphasizes the critical issue of model performance evaluation prior to control strategy modeling. In addition, the procedure recognizes the time constraints for SIP development (9 months) and therefore stresses analyses built around the existing data base while minimizing the need for extensive data processing (e.g., for dispersion models) or additional data collection (e.g., for receptor models).

The first step in PM_{10} SIP development, determining the SIP revision requirements, begins with reviewing the data from ambient monitoring stations to estimate the location, degree, and spatial extent of a potential air quality problem. The degree of the problem may be assessed either directly using available PM_{10} data or indirectly using nonattainment probabilities based on TSP and/or inhalable particulate (IP) data. The assessment process classifies the area surrounding a monitoring site into one of the three groups mentioned previously. The level of effort associated with SIP development is strongly dependent on which of the three groups to which an area is assigned. This is illustrated in Figure 1-1 which shows the SIP requirements for Groups I, II, and III.

For areas classified as Group I, demonstrated or high probability of nonattainment, the next step in PM_{10} SIP development is compilation and evaluation of available data for use in the required modeling. To facilitate

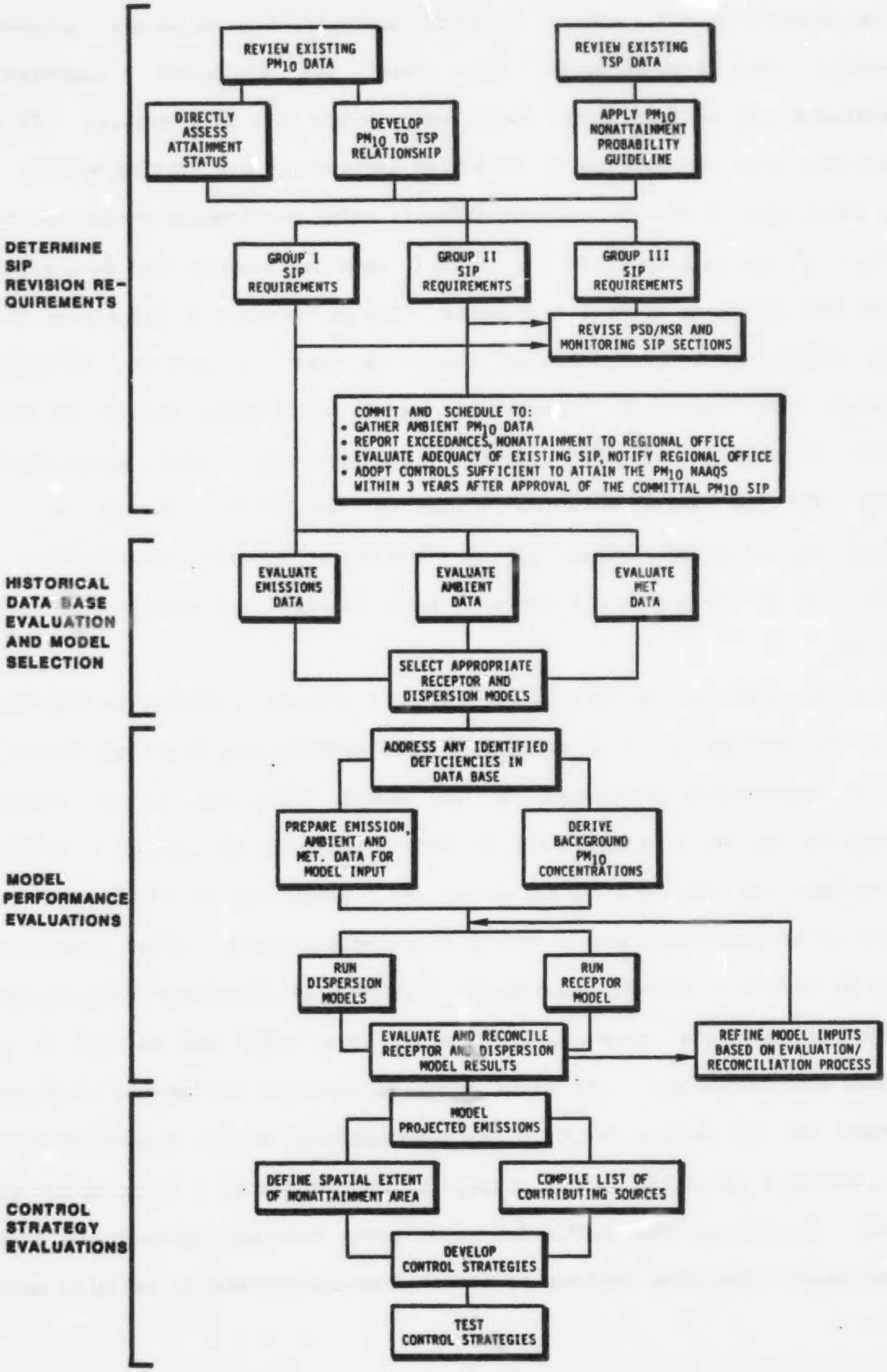

DETERMINE SIP REVISION REQUIREMENTS
REVIEW EXISTING PM10 DATA
REVIEW EXISTING TSP DATA
DIRECTLY ASSESS ATTAINMENT STATUS
DEVELOP PM10 TO TSP RELATIONSHIP
APPLY PM10 NONATTAINMENT PROBABILITY GUIDELINE
GROUP I SIP REQUIREMENTS
GROUP II SIP REQUIREMENTS
GROUP III SIP REQUIREMENTS
REVISE PSD/NSR AND MONITORING SIP SECTIONS
COMMIT AND SCHEDULE TO:
• GATHER AMBIENT PM10 DATA
• REPORT EXCEEDANCES, NONATTAINMENT TO REGIONAL OFFICE
• EVALUATE ADEQUACY OF EXISTING SIP, NOTIFY REGIONAL OFFICE
• ADOPT CONTROLS SUFFICIENT TO ATTAIN THE PM10 NAAQS WITHIN 3 YEARS AFTER APPROVAL OF THE COMMITTAL PM10 SIP
HISTORICAL DATA BASE EVALUATION AND MODEL SELECTION
EVALUATE EMISSIONS DATA
EVALUATE AMBIENT DATA
EVALUATE MET DATA
SELECT APPROPRIATE RECEPTOR AND DISPERSION MODELS
MODEL PERFORMANCE EVALUATIONS
ADDRESS ANY IDENTIFIED DEFICIENCIES IN DATA BASE
PREPARE EMISSION, AMBIENT AND MET. DATA FOR MODEL INPUT
DERIVE BACKGROUND PM10 CONCENTRATIONS
RUN DISPERSION MODELS
RUN RECEPTOR MODEL
EVALUATE AND RECONCILE RECEPTOR AND DISPERSION MODEL RESULTS
REFINE MODEL INPUTS BASED ON EVALUATION/RECONCILIATION PROCESS
CONTROL STRATEGY EVALUATIONS
MODEL PROJECTED EMISSIONS
DEFINE SPATIAL EXTENT OF NONATTAINMENT AREA
COMPILE LIST OF CONTRIBUTING SOURCES
DEVELOP CONTROL STRATEGIES
TEST CONTROL STRATEGIES

Figure 1-1. The Principal Components of the PM_{10} SIP Development Process.

designing dispersion and receptor modeling analyses, the emissions, ambient air quality, and meteorological data bases are evaluated. Important considerations are minimum model input requirements and data quality. This step also addresses the question of selecting appropriate air quality models.

The third step of SIP development stresses model performance evaluation in recognition of the critical need for reliable modeling results for developing effective and efficient control strategies. The performance of dispersion and receptor models must be evaluated prior to use in control strategy development. The essential elements of model performance evaluation for PM_{10} SIP development include: design considerations; data preparation including TSP to PM_{10} emission inventory conversion; derivation of background concentrations; comparison of observed to modeled concentrations; reconciliation of receptor and dispersion model results; and supplemental data collection.

The final step in the PM_{10} SIP process is control strategy development which is the preparation of a verifiable plan showing the level of control needed to demonstrate attainment of the NAAQS. The concept of design concentrations assumes a central role in control strategy development. Design concentrations for the 24-hour and annual PM_{10} NAAQS may be established on the basis of ambient measurements and/or modeling estimates. Other important elements of control strategy development include: establishment of baseline and projected emissions; preparation of model input data; and derivation of background concentrations. One issue which is specific to control strategy development for the 24-hour NAAQS is the computational burden associated with modeling multiple years of 24-hour average concentrations at a large number of receptors. To overcome this difficulty, a directed modeling approach has been developed which identifies regions of elevated concentrations as reliably as a comprehensive analysis but in a more efficient manner. The details of the directed modeling approach are discussed in Section 8.0 of this document.

1.2 Objectives

The objectives of this document are to provide: 1) a structured framework for PM_{10} SIP preparation and 2) examples of the SIP development process. Together, the framework and examples will provide a consistent basis for the effective completion of the SIP revisions required by the PM_{10} NAAQS. Although the complete SIP development process is discussed and illustrated, the use of modeling techniques will be emphasized. Available dispersion and receptor modeling techniques will be applied and their results will be compared. In addition, this document illustrates methods for evaluating the performance of any given modeling approach, and for using two or more approaches in combination to achieve a more reliable and more complete understanding of source contributions (U.S. EPA, 1987b).

Analyses applicable to both the annual and 24-hour PM_{10} NAAQS are demonstrated. The application of models in control strategy development is described. The examples provided include an urban area problem and a problem caused by an industrial source with fugitive dust emissions.

1.3 Overview of Document

This document is organized into ten main sections. The regulatory background of the PM_{10} NAAQS and an overview of the technical approach to PM_{10} SIP development are contained in Section 1.0. A more detailed description of the technical procedures available for PM_{10} SIP development is provided in Section 2.0. Sections 3.0 - 8.0 describe the SIP development process for the example urban area. Section 3.0 is a description of the urban area and associated data bases which are used to develop the example urban area SIP. The procedures used to determine the SIP revision requirements are illustrated in Section 4.0. In Section 5.0, SIP development data needs are discussed. The requirements for SIP development modeling are presented in Section 6.0. Model evaluation is described in Section 7.0 and the derivation and testing of control strategies are covered in Section 8.0. The industrial source example is contained in Section 9.0 and references are provided in Section 10.0.

The urban area example uses a data base developed previously for the Philadelphia Air Quality Control Region (AQCR). This data base was selected because of its versatility, not because of any expected nonattainment problems in this AQCR. In order to illustrate the SIP development process, this data base was modified to create artificial PM_{10} and TSP nonattainment areas.

The industrial area example described in Section 9.0 uses data developed during previous studies in a known PM_{10} nonattainment area. The location of that area is unimportant to the example and is therefore not identified. The data base used for this example was also modified to better illustrate the SIP development process.

2.0 TECHNICAL BACKGROUND

Airborne particulate matter encompasses a wide variety of materials which are introduced to the atmosphere in many different ways and which range in size from submicron up to at least 100 µm in size. The Agency, based upon health effects, has chosen the fraction less than 10 µm in size for regulation.

2.1 Particulate Matter Sources

A wide variety of sources contribute to airborne particulate matter. These sources include point source (stack) emissions from industrial, commercial, and residential locations; fugitive dust (non-point) emissions from industrial processes and materials handling; mobile source emissions from automobiles, trucks, boats, trains; fugitive dust from paved and unpaved roads; natural emissions (such as pollen); forest fires; and aerosols generated by atmospheric chemical reactions.

The PM_{10} primary standards introduce additional requirements to understand the particle size distributions for different types of sources. Certain problems, such as estimating particle settling and deposition, become relatively unimportant since the NAAQS addresses smaller particles; however, particle formation could become more important.

2.2 Modeling Techniques

The two basic categories of modeling techniques available for estimating source contributions to concentrations are dispersion models and receptor models. Dispersion models predict concentrations based on source emissions data and meteorological conditions. In contrast, receptor models use a variety of statistical/mathematical methods to estimate source contributions based on measured physical/chemical properties of ambient and emission samples.

Each type of model provides valuable information and insight regarding particulate matter concentrations. The input requirements for the two methods are quite different. Each model type is discussed in further detail below.

2.3 Dispersion Models

The dispersion models commonly used for regulatory applications are Gaussian models, which employ a relatively simple mathematical framework to predict plume behavior downwind of an emission source. Two short-term Gaussian models which are frequently applied for particulate matter sources are RAM, which is typically used for multi-source urban problems, and ISCST, which is primarily intended for an industrial facility. These two models are recommended for urban and industrial source applications by the EPA Guideline on Air Quality Models (Revised) (U.S. EPA, 1986b). For estimating annual average concentrations, CDM 2.0 is recommended for urban regions and ISCLT is recommended for industrial sources. (Although these models are generally applicable as just described, specific circumstances may be used to justify the use of other models.)

Model input requirements for short-term applications include (but are not limited to) hourly meteorological conditions (wind speed and direction, temperature, mixing height, and atmospheric stability), emission rates, source characteristics (stack parameters, location, particle size distribution, and possibly building dimensions) and receptor locations where model predictions are needed. For annual average modeling, frequency distributions of wind speed, wind direction, and atmospheric stability are entered instead of hourly values. More details on dispersion model inputs are provided in the Guideline on Air Quality Models (Revised) (U.S. EPA, 1986b).

2.3.1 Assumptions

The dispersion modeling approach incorporates a number of assumptions relating to meteorological conditions and to emission rates. Within a given hour, wind speed and direction are assumed to be steady and spatially uniform over the modeling region. Atmospheric turbulence is also assumed to be relatively uniform over the region. The local influence of nearby buildings or emission sources very close to a receptor is generally not considered in modeling for urban-scale applications. Many smaller point sources of emissions are combined into the area source inventory, on the assumption that such sources do not individually dominate local air quality.

The temporal variability of emissions characteristics is often ignored in multi-source applications, due to a lack of available information. Thus, it is generally assumed that normal operating conditions prevail at important sources, and that observed air quality is not influenced unduly by episodes of abnormally high emissions. Daily background air quality concentrations (due to sources outside of the study area) are also assumed to be uniform across the region.

2.3.2 Performance Evaluations

The performance of dispersion models is generally evaluated for a specific application by comparing predicted and observed concentrations at monitor locations. Such an analysis requires meteorological data and an emissions inventory specific to the time period when air quality measurements were taken. By analyzing the differences between observed and predicted values as a function of monitor location and of meteorological conditions, shortcomings in model inputs or assumptions can often be identified.

For regulatory applications, peak short-term concentrations are usually of greatest concern. Comparisons between observed and predicted peak concentrations at a given monitor are of interest both for individual events (paired in time) and regardless of when they occur (unpaired in time). Systematic differences between observed and predicted values at most monitors, such as consistent over- or under-prediction, generally indicate problems with the model and/or meteorological inputs. Uneven results across the network, by contrast, are more often indicative of deficiencies in the emission inventory.

2.3.3 Advantages

Dispersion models offer several advantages, compared to receptor modeling techniques. The primary advantage is the capability to assess impacts for locations, emissions and meteorological conditions different from those for which monitoring data are available. These capabilities are critical for SIP development, since it is important to demonstrate that air quality standards will be achieved everywhere (not just at monitor locations) and to assess the effects of control strategies for nonattainment situations. In addition, the minimum data input requirements for dispersion models are more likely to be fulfilled than for receptor models, at least until a substantial PM_{10} data base analyzed for components is available.

2.3.4 Uncertainties and Limitations

For urban particulate matter studies, the largest uncertainties in dispersion model predictions are those associated with source inputs. This is especially true for short-term (24 hour) predictions, since it is very difficult to estimate or to reconstruct short-term variations in emissions. Uncertainties in emission rates may be small for some source categories (perhaps 10 to 20 percent for point sources) but as large as an order of magnitude for fugitive sources, if no source measurements have been made (U.S. EPA, 1985a).

A second important source of uncertainty is the spatial averaging of emissions which occurs when many small sources are combined into area source emissions. This uncertainty is particularly important for receptor locations in the immediate vicinity of an emission source, such as a roadway, which can produce locally elevated concentrations.

Assumptions about background air quality due to sources outside of the modeled region produce additional uncertainty in predicted concentrations. Background estimates are typically derived from monitoring data and are subject to measurement uncertainties and the limitations of whatever analysis procedure is used to distinguish the background from observed local impacts. Secondary aerosols are generally considered as part of background.

Another important limitation is the lack of a generally accepted method for estimating dispersion model uncertainties.

2.4 Receptor Models

Receptor models provide a means of estimating source contributions to observed particulate matter concentrations. The estimates are provided by a mass balance of aerosol properties measured at receptors with those typical of suspected sources to calculate the contributions which each source could have made to the receptor concentrations. The previous statement suggests the existence of a fundamental receptor model: i.e. the mass balance of linearly additive aerosol properties between the source and receptor. Although numerous aerosol properties and mathematical procedures have been used in receptor models, an expression of mass balance is common to all such models.

Specific receptor models are defined when a set of aerosol properties and a mathematical solution to the mass balance equation have been employed in combination frequently enough to have received a generally accepted name. For example, the chemical mass balance (CMB) model is the common name given to using a weighted least-squares solution to the mass balance equation in combination with multi-chemical characterization of the aerosol (U.S. EPA, 1987c). Receptor modeling techniques are described in Volume I of the EPA Receptor Model Technical Series, entitled Overview of Receptor Model Application to Particulate Source Apportionment (U.S. EPA, 1981a).

Any linearly additive feature of the aerosol can be employed in a receptor model estimation. Some of the physical/chemical methods which have been used to develop the input data for receptor models include:

- X-ray fluorescence (XRF)
- Ion Chromatography (IC)
- Instrumental Neutron Activation Analysis (INAA)
- Automated Scanning Electron Microscopy (ASEM)
- Optical Microscopy (OM)

When applied to ambient samples, the first three methods provide composition data which reflect the combined effects of all sources. In contrast, the microscopic methods (ASEM and OM) provide a means of characterizing individual particles.

When whole filter data are available (from XRF, IC or INAA) statistical solutions to the mass balance equations must be employed to resolve each sample's composition into a set of components from different sources. Receptor models in this category are CMB, multiple linear regression (MLR) and factor analysis (FA). Of these, CMB and MLR provide quantitative source contribution estimates while factor analysis, at its present stage of development, is qualitative.

By examining individual particles, the microscopic methods are able to identify contributing sources with a high degree of confidence. However, relating the particle characterization to the sample as a whole involves many sources of error. Because of these errors, receptor models based on microscopic analysis provide only semi-quantitative source contribution estimates. One source of error is the small number of particles analyzed (ASEM < 1000, OM significantly fewer). In addition, microscopic methods can reliably analyze only particles which are greater than 1 μm in diameter. For a PM_{10} sample, up to half the mass can be less than 1 μm resulting in a strong bias in the microscopy data. For further information on particle identification techniques refer to Volume IV of the Receptor Model Technical Series (U.S. EPA, 1983).

Although receptor models do not require emission rate and meteorological data, this information is valuable for distinguishing among sources with similar emission compositions. For example, wind direction data can help to narrow the list of candidate sources contributing to a given monitor on a given day.

2.4.1 Assumptions

Two assumptions underlie all receptor modeling techniques. The first is conservation of mass, i.e., material from a given source arrives at a receptor independent of other sources and then linearly combines with material from other sources. The second assumption is conservation of relative composition of material from time of emission until arrival at the receptor. Only physical/chemical features of the aerosol which can be justified as meeting the above assumptions should be used in receptor models.

Specific receptor models often require further assumptions. For example, the CMB model assumes statistical independence among source composition profiles. Although satisfactory model results can be expected when this assumption is violated to a limited degree, sources with very similar emission compositions can not be resolved without the measurement of distinguishing features.

2.4.2 Performance Evaluations

The performance of receptor models is evaluated by confirming the model's applicability, examining any reported "goodness of fit" parameters, comparing the observed to predicted mass, and determining the degree of consistency between the estimated source impacts and other evidence. For most receptor models, such an evaluation is generally an ad hoc, qualitative process designed for a specific application. However, for the CMB model, a standardized, seven-step protocol for model performance evaluation has been developed which provides quantitative estimates of precision and validity (U.S. EPA, 1987d). Briefly, the seven steps in the performance evaluation protocol include (U.S. EPA, 1987d):

1) Determine the general applicability of the CMB model to the application at hand;
2) Configure the model by identifying and assembling the source types, source profiles, and receptor concentrations needed for model input. Make a preliminary application of the model to these data;
3) Examine the model's statistics and diagnostics to identify potential deviations from the model assumptions;
4) Evaluate problems which might result from deviations from model assumptions;
5) Make any model changes which solve identified problems and re-run the model;
6) Assess the stability of the model results and their consistency with the preliminary analyses; and
7) Evaluate the model results by reconciling them with other receptor or dispersion model results.

2.4.3 Advantages

The principal advantage which receptor models offer, compared to dispersion models, is greater independence from the emissions inventory and meteorological measurements. Source contributions are estimated directly from observed air quality and source compositions. Receptor modeling requires information regarding emissions composition but does not use mass emission rates. Some receptor modeling techniques will also identify emission sources which have not been included in the emissions inventory. Receptor modeling analyses can also focus on events with observed maximum concentrations and identify contributing sources for these specific conditions. Another advantage is that receptor models are good at quantifying area source impacts.

With respect to the 24-hour average NAAQS, a major advantage of some receptor models (e.g., CMB and OM) is that their application to individual samples makes it possible to quantify source impacts at specific times and locations.

Another major advantage of CMB is that errors are propagated through the calculations such that the uncertainties of source contribution estimates are known.

2.4.4 Limitations and Uncertainties

Receptor model results are specific to the monitor locations and conditions for which ambient samples were analyzed. In the absence of a dense monitoring network, no method of extrapolating results to other locations or other conditions is available, aside from dispersion modeling. For this reason, receptor modeling is most useful for situations where monitoring data show nonattainment, and the central issue is the need to quantify the impact of contributing sources. Even in this situation, however, receptor modeling techniques cannot be used to demonstrate the adequacy of a control strategy at locations other than monitoring stations.

The major limitation of receptor models with respect to PM_{10} SIP development is probably the general inadequacy of the historical data base for PM_{10}. Other important factors which contribute to the uncertainty of receptor model results include similarities between sources and the variability of each source's composition. One example of source similarity is re-entrained dust emissions from paved roads; these emissions originated elsewhere and are often difficult to distinguish from those of the primary sources. Day-to-day variations in emissions composition are a natural consequence of variations in operating conditions. An extreme example of variable emissions composition would be a municipal waste incinerator or resource recovery facility which experiences a wide range of feedstock and operating conditions. Measurement error also contributes to uncertainties in receptor model results. Errors in either source or ambient composition measurements can lead to incorrect source attribution.

The effort and cost of physical and chemical analyses have generally limited receptor modeling studies to a few tens of ambient particulate matter samples (such studies have seldom examined as many as 100 filters) and 20 or fewer source samples. These numbers of samples (ambient or source) constitute an important limitation to study results, since it is sometimes difficult to achieve representative results from a small data sample. In general, the samples should be chosen to represent a variety of meteorological conditions. Further discussion of the selection of ambient samples for receptor modeling analyses can be found in the Protocol for Reconciling Differences Among Receptor and Dispersion Models (U.S. EPA, 1987b).

3.0 DESCRIPTION OF THE EXAMPLE URBAN AREA AND DATA BASE

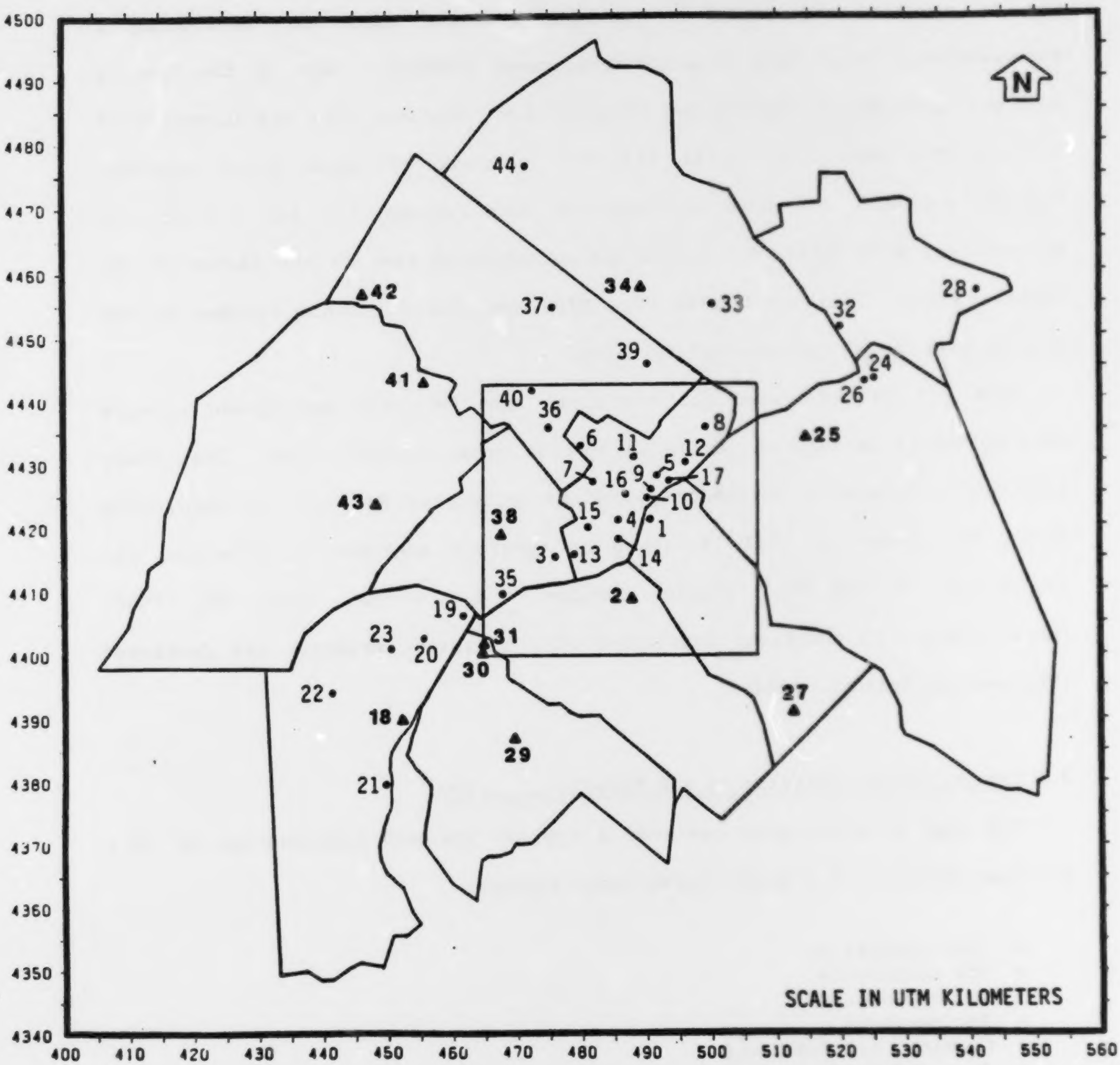
The Example AQCR is a typical urbanized AQCR where PM_{10} SIP preparation may be required and therefore provides a useful basis for developing a representative urban area PM_{10} SIP development example. Maps of the Example AQCR are provided in Figures 3-1 thorough 3-4. The maps show the locations of TSP and PM_{10} monitoring sites and the locations of major point sources. Figures 3-1 and 3-2 give an overview and Figures 3-3 and 3-4 provide successively more detailed views of the metropolitan area in the center of the Example AQCR. This urban area PM_{10} SIP development example focuses on the central portion of the metropolitan area.

Most of the data used for the urban area PM_{10} SIP development example were collected in 1982 as part of a special urban aerosol study. That study included an intensive one-month period of collocated PM_{10} and TSP monitoring during the summer of 1982, followed by numerous analyses to determine the composition of the PM_{10} samples (Dzubay, T.G., et al., 1987; NEA, 1982; PEDCo, 1983). In addition, a detailed PM_{10} emission inventory was developed (Engineering-Science, 1984).

3.1 Typical Characteristics of the Example Urban Area

The example urban area contains a typical mix and distribution of PM_{10} emission sources. The major source types include:

- Coal combustion
- Oil combustion
- Oil refineries
- Incinerators
- Chemical manufacturing
- Iron and steel production
- Grain handling
- Motor vehicle exhaust
- Paved and unpaved road dust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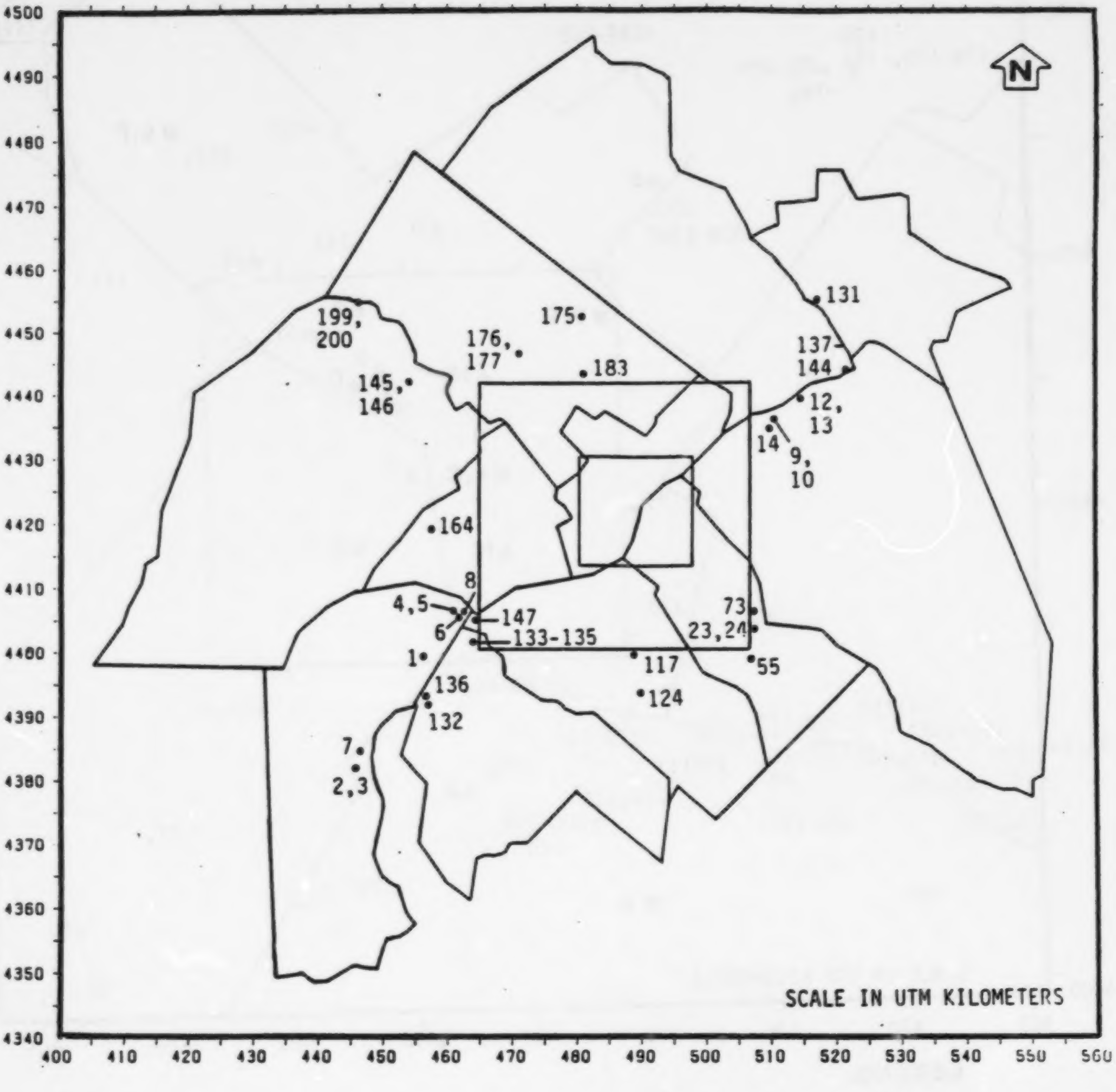
29
21
SCALE IN UTM KILOMETERS

LEGEND

▲ TSP MONITORING SITES USED TO DETERMINE BACKGROUND CONCENTRATIONS

● OTHER TSP MONITORING SITES

Figure 3-1. TSP monitoring sites in the Example AQCR that met minimum sampling criteria in 1982.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73
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133-135
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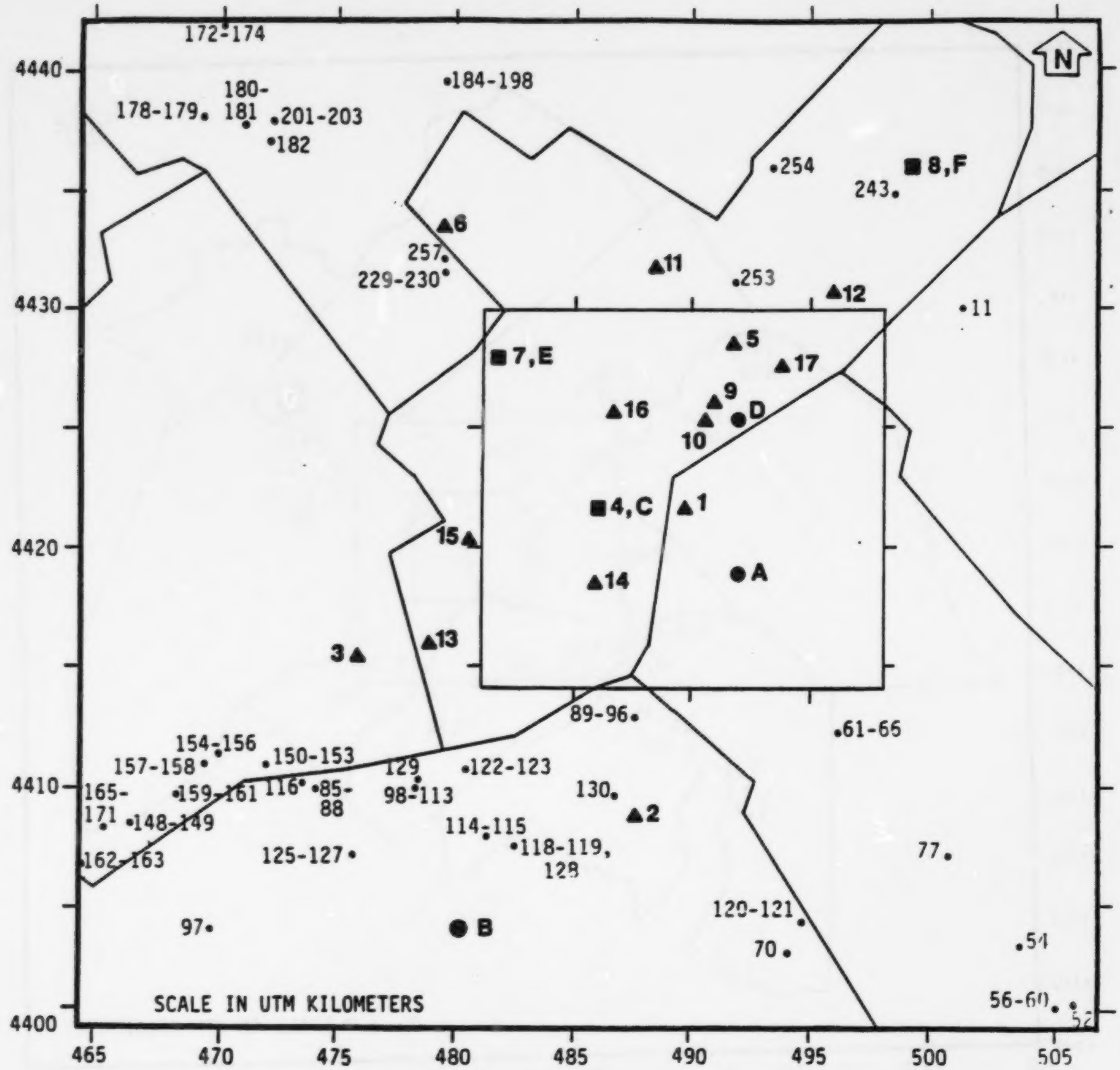
2,3
SCALE IN UTM KILOMETERS

LEGEND

• MAJOR POINT SOURCES

Figure 3-2. Example AQCR study area map depicting major point source locations outside the 42.5 x 42.5 km area source grid.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229-230
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12
11
7,E
5
17
16
9
D
10
4,C
1
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A
3
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89-96
61-66
154-156
157-158
150-153
129
122-123
165-
171
159-161
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85-
88
98-113
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SCALE IN UTM KILOMETERS
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LEGEND:

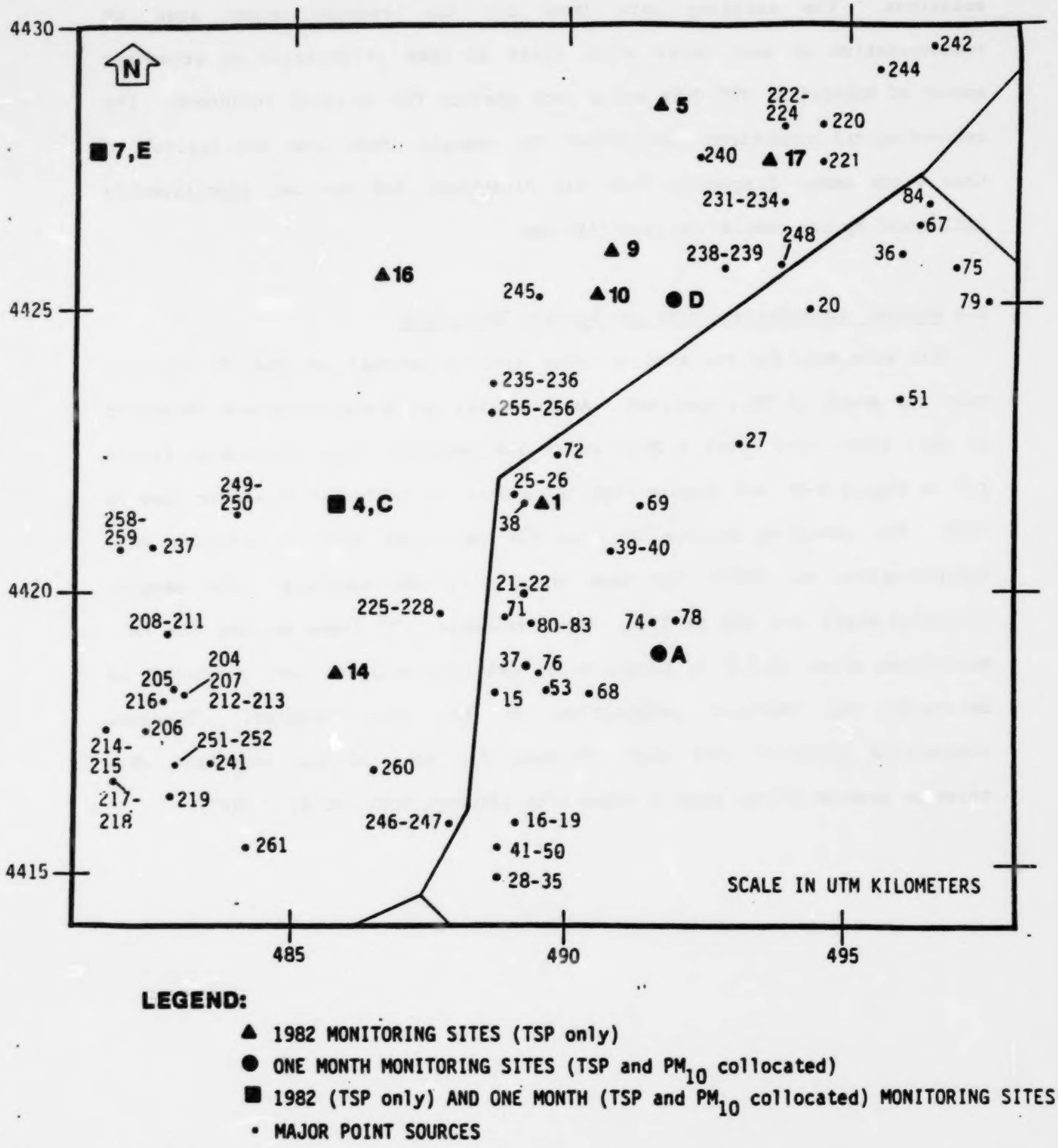
▲ 1982 MONITORING SITES (TSP only)

● ONE MONTH MONITORING SITES (TSP and PM_{10} collocated)

■ 1982 (TSP only) AND ONE MONTH (TSP and PM_{10} collocated) MONITORING SITE

• MAJOR POINT SOURCES

Figure 3-3. PM_{10} and TSP monitor locations and major point source locations in low density areas in the 42.5 x 42.5 km area source grid.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231-234
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238-239
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235-236
255-256
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258-259
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225-228
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80-83
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208-211
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204-207
212-213
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216
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68
15
206
214-215
251-252
241
260
217-218
219
246-247
16-19
261
41-50
28-35
SCALE IN UTM KILOMETERS
LEGEND:
▲ 1982 MONITORING SITES (TSP only)
● ONE MONTH MONITORING SITES (TSP and PM10 collocated)
■ 1982 (TSP only) AND ONE MONTH (TSP and PM10 collocated) MONITORING SITES
• MAJOR POINT SOURCES

Figure 3-4. PM_{10} and TSP monitor locations and major point source locations in the urban center of the Example AQCR study area.

The area also contains many fugitive dust sources, including industrial processes and construction and related activities that produce rock and soil emissions. The existing data base for the example urban area is representative of most large urban areas in that it contains an extensive amount of historical TSP data and a good quality TSP emission inventory. The meteorological conditions that affect the example urban area are typical in that winds occur frequently from all directions and are not significantly influenced by any complex terrain features.

3.2 Unusual Characteristics of the Example Urban Area

The data base for the example urban area is unusual in that it contains only one month of PM_{10} sampling. An intensive one month study was conducted in this urban area where 6 PM_{10} and 6 TSP monitors were collocated (sites A-F in Figure 3-3) and samples were taken every 12 hours for 31 summer days in 1982. The resulting average PM_{10} to TSP ratio was used to estimate PM_{10} concentrations at other locations where only TSP monitors, with samples collected every 6th day in 1982, were available. At three of the six PM_{10} monitoring sites (A,B,F in Figure 3-3), detailed analyses were performed to determine the chemical composition of the PM_{10} samples. Chemical composition profiles were also obtained for some of the important PM_{10} emission sources in the example urban area (Dzubay, T.G., et al., 1987).

4.0 SIP REVISION REQUIREMENTS FOR THE EXAMPLE URBAN AREA

4.1 General SIP Revision Requirements

EPA has established different PM_{10} SIP revision requirements for each of the three groups of areas described previously (see Section 1.0). The requirements are most extensive for Group I areas and least for Group III areas. For all areas, the SIP revisions are required within 9 months of promulgation of the PM_{10} standards. As a minimum, the Prevention of Significant Deterioration (PSD)/New Source Review (NSR) and ambient monitoring sections of the SIP must be revised.

For Group I areas, the SIP must provide for attainment of the PM_{10} standards as expeditiously as practicable, but no later than 3 years after the SIP is approved by EPA (unless a 2-year extention is granted under Section 110(e) of the Clean Air Act). Modeling is required to demonstrate the efficacy of the control strategies needed to attain and maintain the PM_{10} NAAQS.

The SIP revision requirements for Group II and III areas initially do not include modeling or the development of control strategies. However, States may submit a SIP which includes modeling for Group II areas as is required for Group I areas, if they wish. Additional SIP submittal requirements for Group II areas are summarized in Figure 1-1. Further details are provided in the PM_{10} SIP Development Guideline (U.S. EPA, 1987a).

4.1.1 Criteria for Grouping Areas

An area is placed into one of the three groups discussed above based on an analysis of the attainment status of the area. The preferred method of determining the attainment status of a given area is to apply the procedures described in Appendix K of 40 CFR58 to 3 years of PM_{10} data. In the absence of 3 years of reliable PM_{10} data, EPA has developed procedures for the use of the available PM_{10} data supplemented with TSP (or IP) data to determine each area's probability of nonattainment of the PM_{10} standards (U.S. EPA, 1986a). An area may be moved from one group to another if the available ambient data are not deemed representative of present and future PM_{10} concentrations.

Since most states have not been gathering PM_{10} data for 3 or more years, most will assign each area to one of the three groups based on a calculated probability of nonattainment. EPA has defined the nonattainment probabilities for each group as follows: Group I: 95 percent or greater, Group II: 20 to 95 percent, and Group III: less than 20 percent. EPA has also determined that all PM_{10} data gathered before 1987 are subject to some uncertainty. This uncertainty may affect the nonattainment probability calculated for a given area (see the PM_{10} SIP Development Guideline (U.S. EPA, 1987a) for further details).

4.1.2 Defining Area Boundaries

Several techniques have been used by States to define the spatial extent of NAAQS violations, expressed as boundaries of nonattainment areas. Basically, the approaches used can be placed into three categories:

- A qualitative analysis of the area of representativeness of the monitoring site, together with consideration of terrain, meteorology and sources of emissions.
- Spatial interpolation of air monitoring data.
- Air quality simulation by dispersion modeling.

In determining the extent of a PM_{10} nonattainment situation, the use of any one or a combination of the above categories is considered generally acceptable to EPA. The choice of which technique to use depends on the complexity of the PM_{10} problem area and the available data. These choices and techniques are discussed further in the Procedures for Estimating Probability of Nonattainment of a PM_{10} NAAQS Using Total Suspended Particulate or PM_{10} Data (U.S. EPA, 1986a), referred to herein as the PM_{10} Nonattainment Probability Guideline.

4.2 Analyses of the Probability of Nonattainment in the Example Urban Area

The initial step of the PM_{10} SIP development process for the example urban area was to gather and review all existing data from the monitoring stations within the AQCR. This step was designed to collect all TSP, IP and PM_{10} measurements taken over the previous three years at all monitoring sites. The review process for these data consisted of the compilation and verification of the following items for each monitoring station, for each type of data measured (TSP, IP, PM_{10}):

- Years for which data were available
- Yearly sampling schedule (e.g., every sixth day)
- Yearly and quarterly numbers of data points
- Yearly arithmetic means
- Yearly maximum 24-hour values (i.e., first through fourth highest)
- All 24-hour values that exceeded the PM_{10} NAAQS

A partial example compilation for 3 sampling sites in the example urban area is presented in Table 4-1. The table shows data for TSP monitoring sites 2, 4, and 9 (see Figure 3-3).

Following data compilation, the PM_{10} nonattainment status at each monitoring site was determined using appropriate methods described in the PM_{10} Nonattainment Probability Guideline (U.S. EPA, 1986a). For the example urban area, the selected procedures were those which only apply to TSP data obtained using an every sixth day sampling schedule over a 3-year period. Different procedures apply when other sampling schedules or PM_{10} or IP data are evaluated. These other procedures are fully described in the PM_{10}

TABLE 4-1

PARTIAL COMPILATION OF HISTORICAL AMBIENT DATA FROM THREE TSP MONITORING SITES IN THE EXAMPLE URBAN AREA

Site Number	2			4			9		
Year	1982	1981	1980	1982	1981	1980	1982	1981	1980
Sampling Schedule	every 6th day	every 6th day	every 6th day	every 6th day	every 6th day	every 6th day	every 6th day	every 6th day	every 6th day
Number of Data Points	58	59	59	58	59	59	50	55	58
Arithmetic Mean	74	79	74	111	119	111	153	174	159
High 24-hour	164	179	123	246	269	185	529	330	424
2nd high 24-hour	127	159	120	191	239	180	334	282	281
3rd high 24-hour	122	152	118	183	228	177	317	267	272
4th high 24-hour	120	136	113	180	204	170	252	265	242

Nonattainment Probability Guideline (U.S. EPA, 1986a). Software for applying many of the procedures is also available from EPA (U.S. EPA, 1987e). The application of the procedures selected for the example urban area is illustrated below using the data shown in Table 4-1.

The probability determination procedure for the 24-hour average PM_{10} standard is illustrated first using the 24-hour average TSP data for monitoring Site 2. The first step in the probability determination involves obtaining the probability (p) that individual TSP samples represent PM_{10} values greater than the 150 $\mu g/m^3$ 24-hour average PM_{10} standard. Figure 4-1 provides a curve of exceedance probabilities (p_i) for PM_{10} concentrations greater than 150 $\mu g/m^3$, based on 24-hour average TSP concentrations. Based on Figure 4-1 and the data in Table 4-1, the PM_{10} exceedance probabilities for the TSP values (above 150 $\mu g/m^3$) at Site 2 are as follow:

24-hour Average TSP Concentrations ($\mu g/m^3$)	PM_{10} Exceedance Probabilities (p_i)
179	0.020
164	0.008
159	0.005
152	0.001

These low p_i values show that there is a low probability ($\leq$2 percent) that any one of them represents a 24-hour average PM_{10} concentration greater than 150 $\mu g/m^3$.

The next step in the probability determination involves calculating the combined probability (p_a) that no PM_{10} concentrations exceed the 24-hour average PM_{10} standard. This probability of attainment is calculated as follows:

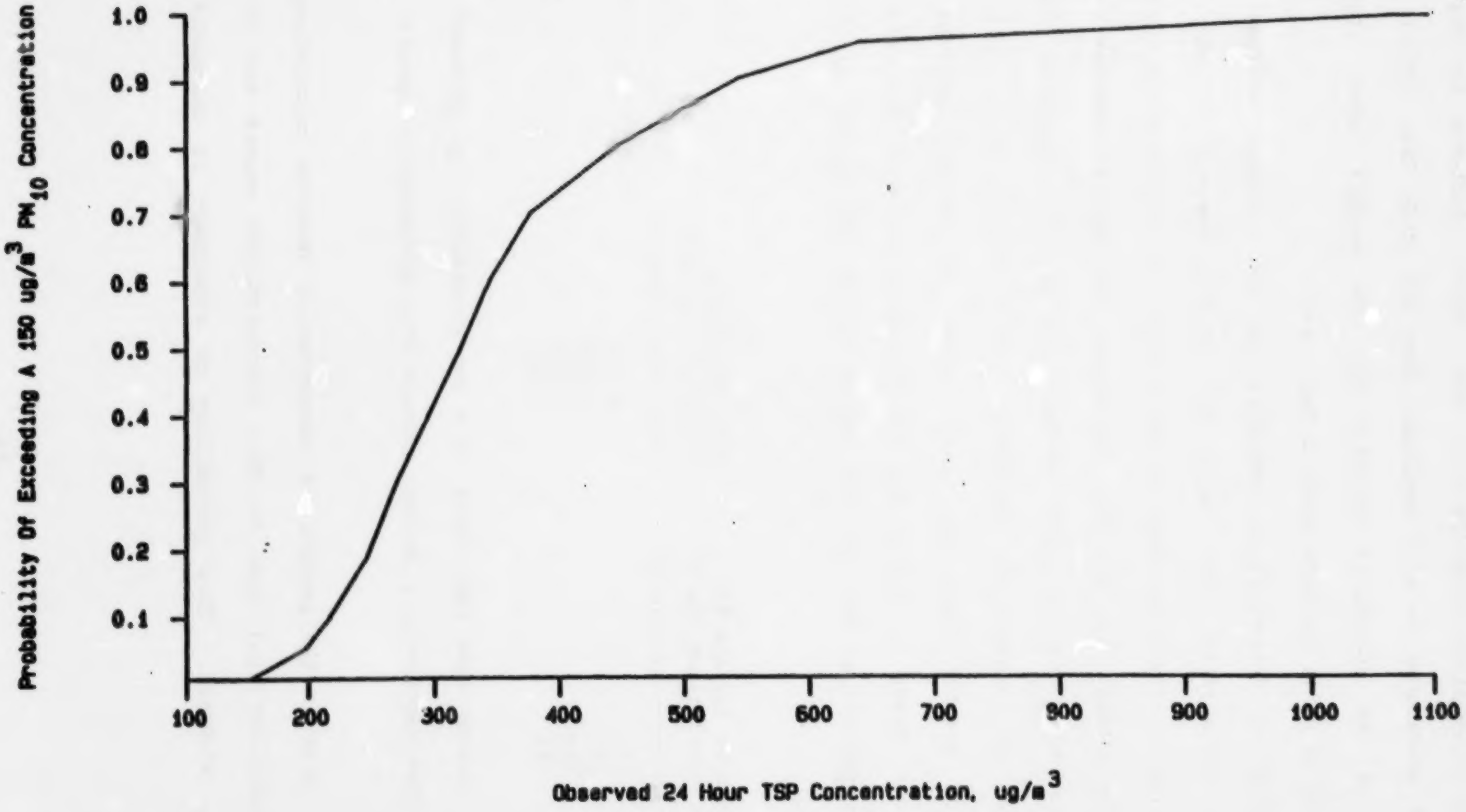

Figure 4-1. Relationship between the probability of exceeding a 150 $\mu g/m^3$ 24-hour PM_{10} concentration and an observed 24-hour TSP concentration. (Figure taken from U.S. EPA,1986a)

$$p_o = \prod_{i=1}^{n} q_i \tag{4-1}$$

where:

$$q_i = (1 - p_i)$$

and $$\prod_{i=1}^{n} = (q_1)\,(q_2)\ldots\,(q_n)$$

For Site 2:

$$p_o = (1-0.02)(1-0.008)(1-0.005)(1-0.001) = (0.98)(0.992)(0.995)(0.999) =$$

$$p_o = 0.996$$

This value is large, so there is a high probability that no 24-hour average PM_{10} value is greater than 150 μg/m^3 and Site 2 is in attainment of the standard.

The last step in the probability determination involves calculating the probability of nonattainment (p_f) of the proposed 150 μg/m^3 24-hour average PM_{10} standard:

$$p_f(1) = 1 - (p_o + p_1)$$

where: (4-2)

$$p_1 = p_o c_1$$

$$c_1 = \sum_{i=1}^{n} (p_i/q_i)$$

Thus, for Site 2,

$$c_1 = [(0.02/0.98)+(0.008/0.992)+(0.005/0.995)+(0.001/0.999)] = 0.0345$$

$$p_1 = (0.966)(0.0345) = 0.0333$$

and $$p_f = 1 - (0.966 + 0.0333) = 0.000674 = 0.0674 \text{ percent.}$$

When the above procedures are applied to the second set of monitoring data from Site 4, the following results are obtained:

24-hour Average TSP Concentrations (μg/m³)	PM_{10} Exceedance Probabilities (p_i)	q_i	p_i/q_i
269	0.27	0.73	0.370
246	0.19	0.81	0.235
239	0.18	0.82	0.220
228	0.13	0.87	0.149
204	0.06	0.94	0.064
191	0.04	0.96	0.042

(Only the six highest TSP values are shown here for illustrative purposes. For this data set, the use of more values does not significantly change the results that follow.)

$p_o = 0.381$

$c_1 = 1.08$

$p_1 = 0.411$

$p_f = 0.208$ or 20.8 percent

When the above procedures are applied to the data shown for Site 9, the following results occur:

24-hour Average TSP Concentrations (μg/m³)	PM_{10} Exceedance Probabilities (p_i)	q_i	p_i/q_i
529	0.88	0.12	7.33
424	0.76	0.24	3.17
334	0.57	0.43	1.33
330	0.56	0.44	1.27
317	0.50	0.50	1.00

(Only the five highest TSP values are shown since the use of more values does not alter the outcome of the results.)

$p_o = 0.00272$

$c_1 = 14.1$

$p_1 = 0.0384$

$p_f = 0.959$ or 95.9 percent.

Data are also provided in Table 4-1 to illustrate one procedure for determining the probability of nonattainment of the annual average PM_{10} standard of 50 μg/m^3. The procedure that follows is only applicable to three years of TSP data collected on a seasonally representative sampling schedule. The PM_{10} Nonattainment Probability Guideline (U.S. EPA, 1986a) contains other procedures applicable to other data sets.

The first step in the procedure selected for illustration involves calculating the average of the annual arithmetic mean TSP concentrations for each of the three sampling years. Figure 4-2 then provides a relationship between the average annual mean TSP concentration and the probability of exceeding the proposed 50 μg/m^3 annual average PM_{10} standard. Listed below are the average annual means and the probabilities of nonattainment (p_f) for the three sampling sites shown in Table 4-1.

Monitoring Site	Average Annual Mean (μg/m^3)	Probabilities of Nonattainment (p_f)
2	76	0.03
4	114	0.66
9	162	0.96

Thus, the probabilities of nonattainment of the annual average PM_{10} standard are 3, 66 and 96 percent, respectively, at the three monitoring sites shown in Table 4-1.

In summary, the 24-hour and annual average nonattainment probabilities were 0.07 and 3 percent for Site 2, 20.8 and 66 percent for site 4, and 95.9 and 96 percent for Site 9, respectively. These nonattainment probabilities place Site 2 in Group III, Site 4 in Group II and Sits 9 in Group I for both

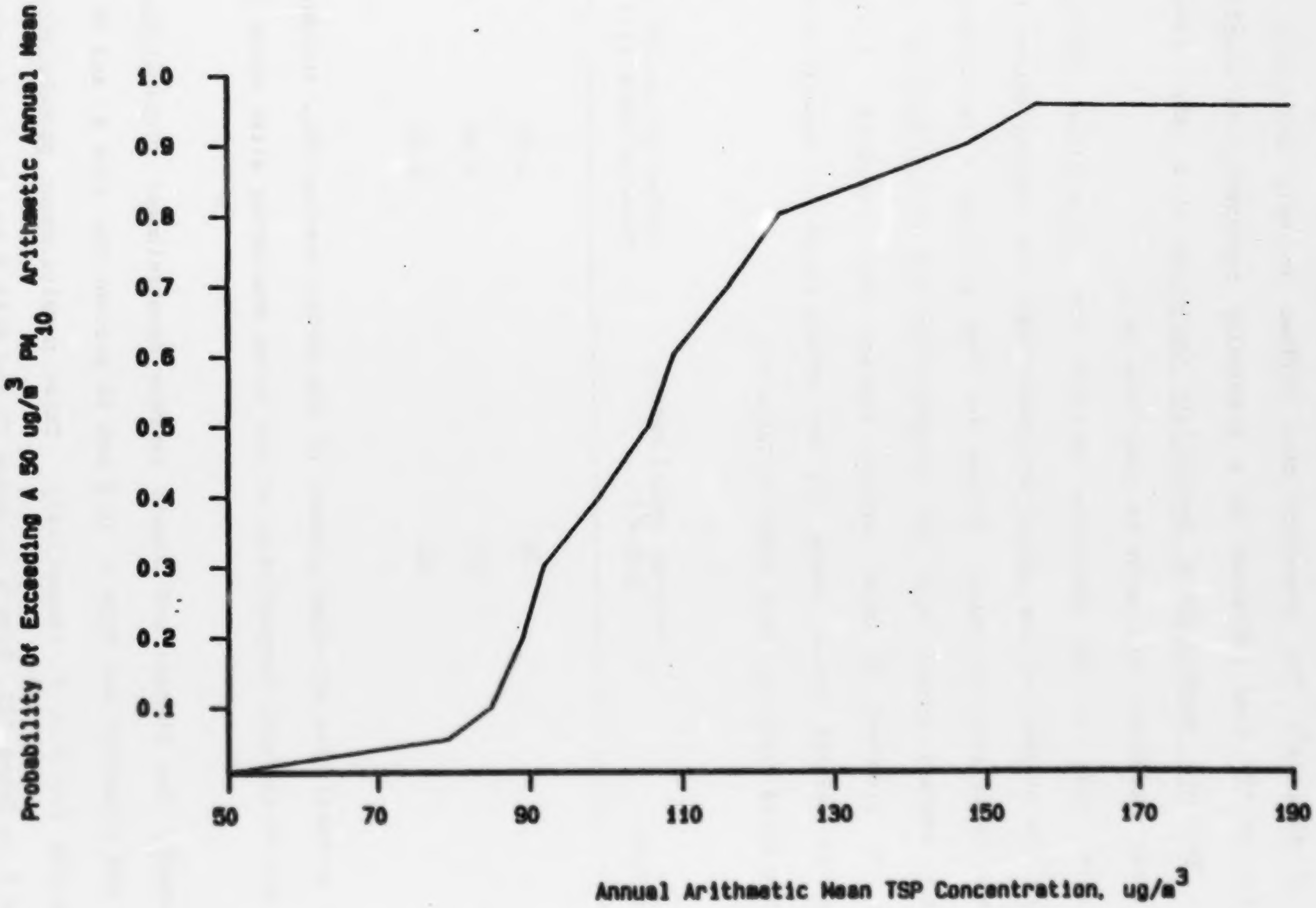

Figure 4-2. Relationship between the probability of exceeding a 50 μg/m^3 annual PM$_{10}$ concentration and an observed annual arithmetic mean TSP concentration. (Figure taken from U.S. EPA, 1986a)

averaging periods. Therefore, the following modeling requirements apply to each of the three sites: 1) Site 2 (Group III), no modeling required; 2) Site 4 (Group II), modeling optional; 3) Site 9 (Group I), modeling required sufficient to demonstrate attainment and maintenance of the PM_{10} NAAQS within 3 years of EPA approval of the SIP. (See Section 4.1 and Figure 1-1 for the other SIP revision requirements applicable to these three sites.)

5.0 EVALUATION OF THE EXAMPLE URBAN AREA DATA BASE

When the need for SIP modeling has been established, the next step is to assemble and evaluate the readily available data that can be used in the required analyses. This is done to facilitate planning the dispersion and receptor modeling analyses. Important considerations are minimum model input requirements and data quality. Given the required time constraints for SIP development (9 months), the preferred approach is to design reliable modeling analyses around the existing data base while minimizing the need for extensive data processing (e.g., for dispersion models) or any additional monitoring (e.g., for receptor models).

5.1 Emissions Data

Dispersion models require emission rate data, receptor models require emission composition data. Existing emission inventories will usually provide the bulk of the information needed for dispersion modeling for PM_{10} SIP development, including the actual emission rate data required for model evaluation analyses and the maximum allowable emission rate data required for control strategy development analyses. In both cases, PM_{10} emission rates must be calculated and updates may be required to include additional types of sources. PM_{10} emission factors are contained in AP-42 (U.S. EPA, 1985a and 1986c). In large urban nonattainment areas, a complete inventory of sources (i.e., major point, area, mobile, fugitive dust) will generally be needed. Less detailed inventories may be adequate in isolated areas dominated by specific sources. For many typical sources (e.g., power plants, motor vehicles) the emission composition data required for receptor models can be obtained from EPA's library of such data (U.S EPA, 1984a). However, the use of site-specific data is necessary for sources unique to the nonattainment area, and is otherwise preferable if available.

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Table 5-1 summarizes an evaluation of the emissions data base for the example urban area. The table lists the inventory contents and the items that were considered when planning the modeling analyses. Table 5-1 shows that the quality of the data base was generally very good, but some limitations are noted. On the plus side, the data were judged to be of good quality on the basis of the thorough and well-documented derivation procedures used. Another major plus is the comprehensiveness of the point, area and mobile source emission inventories. Potential drawbacks and their associated liabilities were 1) the lack of spatial resolution of the area and mobile source inventories which could obscure local source impacts, 2) the incomplete fugitive dust source inventory which could result in the underprediction of total impacts and 3) the lack of receptor model data for some local sources which could hinder the quantification of their impacts. The actual effect of these drawbacks, and the need to make any improvements in the emissions data base, were left to be determined in the model evaluation analyses.

5.2 Ambient Air Quality Data

The first use of ambient air quality data, i.e., the identification of actual or potential nonattainment problem areas, was described in Section 4.0. Ambient air quality data are also needed to perform dispersion and receptor modeling. In dispersion modeling, ambient particulate matter data are needed to determine background concentrations and to evaluate the model. Receptor models require data pertaining to the chemical and physical characteristics of the ambient particulate matter samples.

Table 5-2 provides an evaluation of the ambient air quality data base for the example urban area. The table describes the contents of the data base and its potential uses in the modeling analyses. Table 5-2 shows that the example urban area data base contains no direct measurements of PM_{10} or IP

TABLE 5-1

EVALUATION OF THE EMISSIONS DATA BASE FOR THE EXAMPLE URBAN AREA

Data File	Item Evaluated	Example Data Base Contents	Planning Consideration
Dispersion Model Point Source Inventory	Number of Sources/ Area Covered	16,000/Entire AQCR	Select only critical sources for individual modeling, model remainder as area sources
	Quality of Emissions Data	Recently updated, thorough inventory	Good data quality
	Quality of Stack Parameter Data	Missing for 10% of sources	Obtain/derive for major sources
Dispersion Model Area Source Inventory	Types of Sources/ Data Quality	Includes 17 categories (over 80% of total particulate matter emissions in 3 categories)	Critical inventory categories are fuel use, construction activities and unpaved roads/ good data quality
	Area Covered/ Resolution	1800 km^2 in urban center of AQCR/grid squares: 2.5 km	Localized source impacts potentially obscured
Dispersion Model Mobile Sources Inventory	Derivation/Data Quality	Calculated emissions by road type using local silt measurements	Good data quality
	Area Covered/ Resolution	1800 km^2 in urban center of AQCR/grid squares: 2.5 km	Localized source impacts potentially obscured
Dispersion Model Fugitive Dust Source Inventory	Types of Sources/ Data Quality	Includes industrial source categories only, used limited local data	Other fugitive source impacts indeterminable/data quality uncertain
	Area Covered/ Resolution	1800 km^2 in urban center of AQCR/grid squares: 0.2 and 0.5 km	Localized impacts can be calculated

TABLE 5-1 (Continued)

EVALUATION OF THE EMISSIONS DATA BASE FOR THE EXAMPLE URBAN AREA

Data File	Item Evaluated	Example Data Base Contents	Planning Consideration
All Dispersion Model Inventories	Time Resolution of Emissions	Annual Average (with some data available to calculate variability)	Potential value of modeling using emission rate variability
	Operating Rates	Actual and allowable data available for appropriate sources	Use actual rates for model evaluation and allowable rates for control strategy development
	Particle Size Fractions	Total particulate (with some data available to calculate PM_{10})	PM_{10} emission rates required for modeling
Receptor Model Emission Composition Data	Types of Sources	Includes 7 point sources (selected somewhat arbitrarily), road dust and soil samples	Samples from other local sources preferred, libraried source data needed
	Species analyzed	Chemical elements by XRF only	Carbon and other species may be needed to distinguish and quantify some source impacts

TABLE 5-2

EVALUATION OF THE AIR QUALITY DATA BASE FOR THE EXAMPLE URBAN AREA

Data File	Item Evaluated	Example Data Base Contents	Planning Consideration
Standard TSP Network	Number of Sites	70	Representative background concentrations can be determined for daily and annual periods
	Locations	Throughout AQCR	
	Sampling Schedule	Generally every 6th day	
	Period of Record	5+ years	
Special PM_{10}/TSP	Number of Sites	6 (Figure 3-3, Sites A-F)	Difficult to distinguish between urban and background contributions, locale-specific PM_{10}/TSP concentration ratios can be determined
	Locations	All within urban center of AQCR	
	Sampling Schedule	Every 12 hours	
	Period of Record	31 summer days	
Special PM_{10}	Number of Sites	3 (Figure 3-3, Sites A,B,F)	Receptor modeling has limited applicability in the nonattainment area, samples limited to a single season
	Locations	None in the nonattainment area	
	Sampling Schedule	Every 12 hours	
	Period of Record	31 summer days	
	Types of Instrumentation	Dichotomous samplers	Adequate for some receptor modeling, but additional metals, sulfate, and carbon composition data may be needed for definitive analyses
	Filter Media	Teflon	
	Analyses Performed	XRF	
	Particle Size Data	Fine and coarse fractions	
	Particle Composition Data	Certain metals	
	Data Quality	Good	

background concentrations, but the data base does contain sufficient data to estimate PM_{10} background concentrations based on TSP background concentrations and measured PM_{10}/TSP concentration ratios. The example urban area data base for receptor modeling includes several sites, a large number of filter samples and chemical characterization data for many essential species, but none of the sites is located in the nonattainment area and only summertime samples were collected. The determination of the effects of the shortcomings in the ambient air quality data base was left to the model evaluation analyses.

5.3 Meteorological Data

Meteorological data comprise an essential part of the input to dispersion models. For receptor models, meteorological data are not required as model input, but serve to guide the selection of input data and the interpretation of analysis results.

An evaluation of the meteorological data base in the example urban area is presented in Table 5-3. The table shows that the example urban area data base contains two meteorological data files, one consisting of site-specific data and the other of National Weather Service (NWS) data. The information presented in the table highlights some criteria for selecting the most appropriate data for SIP development modeling. In general, site-specific data may be desirable for spatial representativeness, but the extensive resources needed to obtain and process good quality data will usually mandate the use of NWS data. Even if NWS data are used for dispersion modeling, site-specific data can be used to plan and interpret the results of receptor modeling analyses.

NWS data were selected for all dispersion modeling analyses in the example urban area because of their good quality, general spatial representativeness, and necessary length of record, as shown in Table 5-3.

TABLE 5-3

EVALUATION OF THE METEOROLOGICAL DATA BASE FOR THE EXAMPLE URBAN AREA

Data File	Item Evaluated	Example Data Base Contents	Planning Consideration
Site-Specific Data	Parameters Measured	Surface wind direction and speed, temperature and solar radiation; vertical temperature and wind profiles	Software needed to prepare data for dispersion model input
	Spatial Representativeness	Monitoring conducted at 6 locations in the study area	Only one set of data (e.g., from one location) can be used for dispersion model input
	Period of Record	31 summer days	5 years of data needed to assess compliance with NAAQS
	Data Quality	Much missing data and remainder of uncertain quality	Poor quality data not suitable for SIP development modeling
National Weather Service Data	Parameters Measured	Surface wind direction and speed, temperature, cloud cover, ceiling heights; upper air temperature profiles	Existing preprocessor program can be used to prepare model input data (i.e., stabilities, mixing heights)
	Spatial Representativeness	Surface data: local airport upper air data: nearest available	Mixing height values may be unrepresentative when based on distant-site upper air data
	Period of Record	5+ years	Meets needs of SIP development modeling
	Data Quality	Very Good	Suitable for SIP development analyses

6.0 REQUIREMENTS FOR SIP DEVELOPMENT MODELING WITHIN THE EXAMPLE URBAN AREA

6.1 General Requirements

In Section 4.0, ambient data were presented for three representative monitoring sites in the example urban area. At one of the sites, the probability of nonattainment was shown to be sufficiently high so that the required SIP revision must include the selection of control strategies and a demonstration of their adequacy to attain and maintain compliance with the NAAQS. Section 51.12 of 40 CFR requires that the adequacy of a control strategy for attainment and maintenance of NAAQS be demonstrated by means of a dispersion model or other procedure which is shown to be adequate and appropriate for this purpose. The following sections summarize the criteria used to select appropriate models and the application of those criteria to the example urban area data base.

6.1.1 Model Use Options

EPA policy provides three options for estimating the air quality impact of emissions of PM_{10} using dispersion and receptor models: 1) use of receptor and dispersion models in combination (preferred), 2) use of dispersion models alone, and 3) use of receptor models in conjunction with a proportional model. The recommended hierarchy for the use of dispersion and receptor models in PM_{10} source apportionment is shown in Table 6-1. The selection of a modeling option adequate to demonstrate compliance with the NAAQS is a function of model applicability and the available data base.

Guidance on the applicability and use of dispersion models is contained in the Guideline on Air Quality Models (Revised) (U.S. EPA, 1986b). Detailed information on the applicability and use of receptor models is contained in the 6-Volume Receptor Model Technical Series (U.S. EPA, 1981a, 1981b, 1987c, 1983, 1984b, 1985b). Additional guidance on this subject is contained in the PM_{10} SIP Development Guideline (U.S. EPA, 1987a).

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TABLE 6-1

RECOMMENDED APPROACHES FOR PM_{10} SOURCE APPORTIONMENT
(Table taken from U.S. EPA, 1987a)

Ambient Data Base Available	
PM_{10}	TSP*
Applicable dispersion and receptor model	Applicable dispersion model corroborated by ASEM or optical microscopy**
Applicable dispersion model	
Receptor methods (at least 2) CMB with corroborating method	Applicable dispersion model

* TSP may be used as a surrogate, where PM_{10} data bases are inadequate.

** Other receptor models such as Mass Balance may be used if fine particle data (generally less than 2-3 micrometers) are collected in addition to TSP.

6.1.2 Model Selection

Factors that influence the selection of dispersion models include 1) the time period of interest, 2) urban/rural considerations, 3) terrain complexity, 4) source types/configurations and 5) the availability of required model input data. The dispersion models recommended for general use in estimating PM_{10} concentrations are shown in Table 6-2.

Factors involved in the selection of receptor models include 1) one's familiarity with the sources and the emissions, 2) the availability of particle size data, 3) the chemical similarity of different source emissions, 4) the need to distinguish individual source (from source category) impacts, and 5) the time period of interest. The criteria for selecting an appropriate receptor model are shown in Table 6-3.

6.2 Dispersion Models Selected for the Example Urban Area

The RAM and CDM 2.0 dispersion models were selected for the example urban area analyses based on the applicability criteria contained in the aforementioned EPA guideline documents. Specifically, the RAM and CDM 2.0 models are designed for use in urban, flat terrain areas to provide estimates of 24-hour and annual average concentrations, respectively. Models with greater capabilities such as those that address particle settling and deposition are not needed for PM_{10}, and no generally recommended models are yet available to account for secondary particle formation in the atmosphere.

The comprehensive emission inventory described in Section 5.0 is well suited to RAM and CDM 2.0 dispersion modeling because these models can accept the available area source data input. The applicability of the RAM and CDM 2.0 models is also enhanced because the available NWS meteorological data are spatially representative and, with a minimum of effort, can be processed into

TABLE 6-2

DISPERSION MODELS APPLICABLE TO PM_{10} ANALYSES[1]
(Table taken from U.S. EPA, 1987a)

1 to 24-Hour Average	Annual Average	Screening Techniques[2]
CRSTER	CRSTER	PTPLU-2
MPTER	MPTER	COMPLEX 1
RAM	RAM	VALLEY
ISCST	ISCLT	
	CDM 2.0	

[1] For more information concerning the applicability of these models, consult the Guideline on Air Quality Models (Revised) (U.S. EPA, 1986b). As noted in this document, these models may also be used for TSP modeling analyses in conjunction with a suitable TSP emission inventory, as a surrogate, where PM_{10} data bases are inadequate.

[2] These models are considered to be screening techniques for use prior to a more refined analysis as outlined in the Guideline on Air Quality Models (Revised) (U.S. EPA, 1986b).

TABLE 6-3

SELECTING FEASIBLE SOURCE APPORTIONMENT METHODS BASED ON DATA AVAILABILITY AND SOURCE CHARACTERISTICS

(Table taken from U.S. EPA, 1987a)

	Fine	Coarse	Sources Known	Sources Unknown	Chemical Similarity	Finger-Prints Dis-Similar	Isolated Single Source	Air-shed (Source Categories)	Air-shed Specific Sources (Within Category)
Chemical Mass Balance (CMB)	Y	Y	Y		a,b,Y	Y	Y	Y	b,Y
Factor Analysis (FA)	X	X	X	X	b,X	X	X	X	
Automated Scanning Electron Microscopy (ASEM)	c,X	X	X	X	b,X	X	X	X	b
Optical Microscopy (OM)	c,X	X	X	X	b,X	X	X	X	b
Dispersion Model (DM)	YY	YY	YY		YY	YY	YY	YY	YY

a - Initial use of Factor Analysis may be helpful.

b - Useful if a source can be isolated from other similar sources by wind direction. Method usually cannot otherwise distinguish between sources in same category.

c - Useful for fine particles larger than 1.0 µm.

X - Appropriate to use in conjunction with CMB or DM.

Y - Appropriate to use with DM or FA, ASEM or OM.

YY - Appropriate to use.

the required input formats (using the RAMMET and STAR programs, respectively). These models also allow for the calculation of impacts at multiple receptors, a capability needed to determine the spatial extent of the nonattainment area.

An essential prerequisite to the use of dispersion models in SIP development is the availability of reliable background concentration estimates. As shown in Section 5.0, the existing example urban area data base contains sufficient data to produce such estimates.

Since there are dispersion models available that are applicable to the nonattainment problem, these models should be used in the SIP development analyses. Dispersion models would not be used only if there were no applicable models available.

6.3 Receptor Models Selected for the Example Urban Area

Upon review of the available data base (see Tables 5-1 and 5-2), and the criteria for receptor model applicability (see Table 6-1 and the aforementioned receptor modeling documents), the CMB model was selected for the example urban area analyses for SIP development. Although the data base is not all-encompassing, it does contain particle composition data in both the fine and coarse fractions for many ambient samples and several site-specific sources suspected of being important contributors to the nonattainment problem. Therefore, useful CMB analyses can be performed when site-specific source signatures are supplemented with other representative source signatures from the EPA Source Composition Library (U.S. EPA, 1984a).

The availability of particle size data will enable a distinction to be made between the impacts of sources of fine and coarse particles. However, the lack of data for certain species (e.g., carbon and sodium) may result in the need for supplemental filter analyses to distinguish between otherwise similar sources. The availability of many ambient samples makes it possible to average the results of a number of CMB analyses to obtain an estimate of long-term (e.g., annual) source contributions.

Since the CMB receptor model is applicable and the necessary data are available, the first (and preferred) SIP development option of using dispersion and receptor models in combination is appropriate for the example urban area. A receptor model would not be used only if there were no applicable model and necessary data available.

6.4 Preliminary Analyses

An efficient approach to SIP development modeling should include preliminary or screening modeling analyses to obtain a qualitative assessment of the cause(s) of nonattainment prior to embarking on any large scale modeling analyses. This step can include both dispersion and receptor modeling. The screening analyses performed to address the nonattainment problems identified in the example urban area in Section 4.0 are described below.

6.4.1 Screening Dispersion Modeling

Screening modeling was performed to determine if any of the point sources in the emission inventory are likely to have large impacts at the monitoring sites identified as having a high probability of nonattainment. The selection of the point sources to be subject to the screening modeling was based on the source's TSP emission rate (Q), an exponential term which included stack height (H_s) and distance (D) from the monitor. Those sources with the greatest QH_s/D ratios were modeled using standard screening procedures (U.S. EPA, 1981c) to determine maximum 1-hour average impacts. The screening modeling results showed that no single point source or group of point sources can be expected to be the primary cause(s) of nonattainment. However, the largest contributors were found to be coal-fired power plants.

6.4.2 Receptor Modeling

Potentially useful preliminary receptor modeling methods include optical microscopy, automated scanning electron microscopy, microinventories, chemical emission inventories, factor analysis and CMB. Of these, only the chemical emission inventory and CMB can be performed using the available data base. For the example urban area, one of the high concentration ambient samples was selected for each of the three monitors with available chemical composition data, and a CMB analysis was performed to obtain an estimate of source contributions. The source signatures used for this analysis were all obtained from the EPA Source Composition Library (U.S. EPA, 1984a) and included the types of point sources identified in the screening dispersion modeling analyses. Also included was a road dust source signature, since this type of source is expected to be a major contributor in urban areas.

The preliminary CMB results indicated that road dust is the major contributor to the PM_{10} at all three monitors where receptor model data were available in the example urban area. However, additional analyses using site-specific source signatures would be required for most sources to obtain quantitative results for each type of source.

6.5 Comprehensive Analyses

Comprehensive modeling analyses will generally be required in urban areas for several reasons. Urban area nonattainment problems often are caused by a complicated mix of many sources and source types such that identification of the contributing sources and quantification of their impacts will be difficult. The development of cost-effective control strategies will depend on an ability to reliably attribute most of the particulate matter to specific sources or source types. The selection of cost-effective controls may require resolution of minor source or source type contributions if such controls cannot be applied to the major contributors. Comprehensive dispersion modeling analyses may also be needed to define the boundaries of the nonattainment area and test control strategy effectiveness.

For the example urban area, the preliminary dispersion and receptor modeling analyses showed that more thorough analyses were required to obtain definitive results. They also provided valuable insight into a likely cause of the nonattainment problem, i.e., fugitive dust from roads and other sources. Therefore, subsequent efforts focused on quantifying the emissions and impacts of both coal-fired power plants (based on the screening dispersion model results) and fugitive dust sources.

7.0 DEMONSTRATING RELIABLE MODEL PERFORMANCE FOR THE EXAMPLE URBAN AREA

The results of air quality models form the foundation of most control strategy decisions. The availability of reliable modeling results is critical for developing effective and efficient control strategies. Therefore, the performance of dispersion and receptor models must be evaluated prior to use in control strategy development. This section describes procedures for evaluating selected air quality models (dispersion and receptor) for use in PM_{10} SIP development. The first subsection covers general considerations while the remainder of the chapter addresses the evaluation methods used for the example urban area. The topics covered for the example urban area include: data preparation; derivation of background concentrations; comparisons of observed to dispersion modeled concentrations; and reconciliation of receptor and dispersion model results.

7.1 General Considerations

7.1.1 Development of PM_{10} Emission Inventories

Evaluation of dispersion models in terms of their abilities to reliably predict ambient PM_{10} concentrations requires a PM_{10} emission inventory. The PM_{10} SIP Development Guideline (U.S. EPA, 1987a) contains PM_{10} emission factors and PM_{10}/TSP fractional multipliers that may be applied to existing TSP inventories. Further information on PM_{10} emission factors are contained in AP-42 (U.S. EPA, 1985a and 1986c). Many of the procedures for developing a PM_{10} emission inventory are the same as those which have been employed in the past for TSP inventory development. As with TSP, the four main types of PM_{10} sources are point, area, mobile and fugitive. In areas exceeding the 24-hour NAAQS, adding temporal resolution to a PM_{10} emission inventory may be important. Improving the existing methods of estimating the emissions of sources contributing condensable and secondary aerosol is also of

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greater concern for PM_{10} emission inventories. Finally, resources must be allocated for software development tasks which are inevitable in emission inventory compilation.

Evaluation of receptor models requires reliable information on the chemical/physical characteristics of the particles emitted by major contributors to ambient PM_{10} concentrations. The type of source characterization needed is dependent on the specific receptor oriented approach undergoing evaluation (U.S. EPA, 1984b). For the purpose of this discussion, the use of the CMB model will be assumed. Emission composition data are readily available for many source types. The EPA Source Composition Library (U.S. EPA, 1984a) is the principal repository for existing source composition profiles or "fingerprints". Although the fingerprints in the source library may be used for CMB modeling, more reliable results are obtained using airshed-specific source composition data developed by collecting and chemically analyzing emission samples from local sources. Because the CMB model is strongly dependent on the conservation of relative composition assumption, more reliable CMB results can be obtained by collecting source samples in a manner which minimizes deviations from this assumption.

7.1.2 Compilation of Ambient PM_{10} Data

Dispersion model performance evaluations are based on comparisons between measured and modeled concentrations. However, the lack of a large historical PM_{10} data base will inhibit the evaluation process for many areas. For locations for which only sparse sets of PM_{10} observations exist, it will be necessary to derive ambient and background PM_{10} concentrations from historical TSP data. Transformation of TSP concentrations to PM_{10} concentrations is accomplished most reliably by applying a site specific

PM_{10} to TSP ratio. In the absence of a site specific ratio, AQCR, State, regional or national average TSP to PM_{10} ratios may have to be applied. Further suggestions on the use of TSP measurements as a surrogate for PM_{10} are given in Appendix D of the PM10 SIP Development Guideline (U.S. EPA, 1987a).

As in the case of emissions data, the use of ambient air quality data in PM_{10} SIP development often requires a substantial amount of data preparation. This may include data processing to obtain data for use in: 1) dispersion model evaluation comparisons; 2) receptor model input; 3) background concentration determinations; and 4) PM_{10}/TSP concentration ratio calculations.

7.1.3 Prioritization of Monitoring Sites

In general, model evaluation analyses should employ as many monitoring sites as possible although particular emphasis should be placed on results for the sites within the boundaries of the nonattainment area. Model credibility is enhanced by the correct prediction of concentrations at both attainment and nonattainment monitors. Nevertheless, monitors should not be included if they are located outside the territory covered by the emission inventory used in the model.

7.1.4 Meteorological Data

Dispersion models require input of meteorological data. For example, RAM requires input of hourly wind direction, wind speed, atmospheric stability, temperature, and mixing height data, while CDM 2.0 requires input of a joint-frequency distribution of wind direction, wind speed, and atmospheric stability in the STAR (stability array) format. In addition, model performance evaluation requires identification of critical meteorological conditions. For dispersion modeling, the issue of critical meteorological conditions pertains primarily to the 24-hour PM_{10} NAAQS. Two sets of critical conditions are of concern. One set is that which produces the highest observed concentrations and the other is that which produces the highest modeled concentrations.

For receptor modeling, critical meteorological conditions must be considered with respect to the annual average NAAQS. In general, receptor modeling is applied to a limited subset of the available ambient samples in order to develop an estimate of the annual average source contributions. This subset should be chosen to be representative of the distribution of meteorological conditions which occur at the site (U.S. EPA, 1984b). To ensure the representativeness of the subset, probability sampling should be employed to select the subset from the population of available ambient samples. Two probability sampling techniques which have been used to select ambient samples for receptor modeling analysis are random and stratified sampling.

7.2 Data Base Preparation for the Example Urban Area

A considerable amount of data manipulation was required to prepare the data base required for the model evaluation analyses. This subsection describes, for the example urban area, the procedures used to prepare the emissions, ambient, and meteorological data and the selection of receptor locations employed in the analyses.

7.2.1 Emissions Data

The starting point for the example urban area PM_{10} emission inventory was the existing annual average TSP emission inventory described in Section 5.1. The procedure employed to conduct the TSP to PM_{10} transformation followed the recommendations found in the PM_{10} SIP Development Guideline

(U.S. EPA, 1987a). Two types of inventories were prepared for model input; one comprised of major point sources and the other containing area sources (which included all other source types). The existing inventory contained data for 3867 point sources within the modeling region. Selection of 261 major point sources was accomplished through the use of a screening procedure based on the QH_e/D ratios described in Section 6.3.1. Source-specific PM_{10}/TSP ratios were then applied to the major point sources to complete the annual average point source PM_{10} emission inventory. All other sources (i.e., area, fugitive, mobile, and minor point sources) were placed in the area source inventory. A general PM_{10}/TSP emission ratio was applied to the minor point sources based on the average ratio found for the major point sources. Other sources in the area source inventory were scaled with source-specific PM_{10}/TSP emission ratios. This completed the compilation of the PM_{10} emission inventories as required for the annual average model evaluation.

The annual average PM_{10} emission inventories were then used to derive temporally resolved PM_{10} emission inventories. The temporal resolution was needed in order to evaluate the importance of seasonal, daily (e.g., weekday/weekend) and diurnal emission rate variations.

To evaluate the dispersion model with respect to estimating 24-hour average PM_{10} concentrations, hourly emission rates were calculated for each of the 61 TSP sampling days (every sixth day) in the test year (1982) selected for the example urban area. Equation 7-1 below was used to derive the hourly emission rate for each source for each of the 61 TSP sampling days:

$$PM_{10}(hour) = PM_{10}A*(SF/NDS)DF*HF*252 \qquad (7\text{-}1)$$

where: $PM_{10}A$ = actual annual PM_{10} emission rate (TPY),
SF = fraction of $PM_{10}A$ in a given season,
NDS = number of days in a particular season,
DF = 7/number of days per week the source was operative (e.g., DF = 7/5 = 1.4 if the source was operative 5 days per week, Monday through Friday; and DF = 0 for Saturdays and Sundays),
HF = 1/number of hours/day source is operative (e.g., if the source is operative 8 hours per day, HF = 1/8 for the 8 operative hours, and HF = 0 for the 16 inoperative hours. Note, a starting time of 7-8 AM was assumed for sources that operated for less than 16 hours per day.), and
252 = (2000*453.59)/3600 to convert tons/hour to g/sec.

Numerous sources of information were consulted in order to glean appropriate values for SF, DF, and HF for each source in the inventories. Obtaining and applying these values was a labor intensive process which required considerable software development.

In order to evaluate the CMB receptor model, emission composition data were required. This requirement was fulfilled by the collection and analysis of emission samples from seven of the largest local point sources (Dzubay T.G., et al., 1987). A size-segregating dilution sampler was used to collect the stack emissions. In addition to the point sources, road dust and soil samples were collected from several locations, resuspended onto filters and chemically analyzed. X-ray fluorescence was employed to determine the trace element composition of the source samples. Chemical profiles for other sources were obtained from the EPA Source Composition Library (U.S. EPA, 1984a).

7.2.2 Ambient Air Quality Data

A limited amount of data preparation was needed to produce the PM_{10} data used in the RAM and CDM 2.0 model evaluation analyses for the example urban area. The starting point in preparing these data was the file provided by EPA which contained TSP concentrations every sixth day for 1982 at the 59 operating monitoring sites in the example AQCR. Of these 59 sites, only 17 (see Figure 3-3) were located sufficiently within the boundaries of the area source inventory to be suitable for use in dispersion model evaluation analyses. An airshed specific PM_{10}/TSP ratio (0.8) was applied to the TSP data to estimate PM_{10} concentrations. This ratio was the average of the PM_{10}/TSP ratios observed at four of the six monitoring sites where collocated samples were collected during the one-month intensive sampling program in the example urban area (Sites A, B, C, and E in Figure 3-3). Data from the other two monitoring sites were not used because of excessive fugitive dust influence at one site and invalid PM_{10} and TSP data at the other site (Sites D and F, respectively, in Figure 3-3).

Software was developed to transform the receptor model data received from EPA into the format required by the CMB model. This software made it possible to readily perform CMB modeling with any of the samples collected at the three PM_{10} monitors.

7.2.3 Meteorological Data

The data preparation for the example urban area began with the file of hourly NWS meteorological data plus mixing heights for all of 1982. Using a combination of the RAMMET preprocessor program and appropriate software, the hourly data for the every-sixth-day air quality monitoring schedule were extracted for use in RAM. Additional software was used to read the RAM data and create annual and seasonal Day/Night STAR data (based on the 61 TSP sampling days) for use in CDM 2.0.

7.2.4 Receptor Locations

The only receptor locations used in the model evaluation analyses consisted of TSP monitor site locations. During 1982, a sufficient number of samples was collected to calculate annual statistics at 44 of the 59 operating TSP monitoring sites in the example AQCR. These 44 sites are shown in Figure 3-1. Of these 44, 17 (Figure 3-3) were located at least 2.5 km inside the edges of the 42.5 by 42.5 km area source inventory grid. Only these 17 were used as receptors in the dispersion model evaluation analyses.

7.3 Derivation of Background Concentrations

Background concentrations are essential to dispersion model evaluation analyses. In dispersion modeling analyses, background concentrations are generally considered to be those concentrations caused by sources that are not included in the emission inventory used by the model. Therefore, dispersion model evaluation analyses are performed by comparing measured minus background concentrations to modeled concentrations.

The derivation of the desired background concentrations began with the identification of monitoring sites that could be used for that purpose. In order to do this, the 44 TSP monitoring sites that obtained statistically representative data in the AQCR in 1982 were plotted on a map of the study area (see Figure 3-1). Potential background monitoring sites were defined as those located outside the urban center of the 42.5 by 42.5 km area source inventory grid. Also excluded from consideration as background sites were those not located in generally rural or undeveloped areas. Of the 44 sites, 12 were selected as being likely to record background concentrations under at least some meteorological conditions. These 12 background sites are indicated in Figure 3-1.

The RAM model required 24-hour average background concentrations for each of the 61 TSP sampling days, while the CDM 2.0 model needed the 61-day average background concentration. The 24-hour average background concentration for a specific day was taken as the average concentration from the subset of the 12 background monitoring sites which were upwind of the example urban area for that day. The annual average background concentration was calculated as the mean of the sixty-one 24-hour average values.

7.4 Model Operation

Prior to the use of the models, the selection of model options was required. This section describes the options employed for the RAM, CDM 2.0, and CMB modeling analyses which were conducted.

The RAM model (U.S. EPA, 1987f) was operated with the control options set to:

IPOL = 4, only particulate matter considered
MUOR = 1, urban mode
Z = 0, no consideration of receptor height
IOPT(38) = 1, the regulatory default option for urban area applications
HANE = 10.

Area source input parameters were as follows:

FH = 0.5, which assumes that area source heights were comprised of equal contributions from physical stack height and plume rise.

XLIM = 61, this value is approximately the length of a diagonal within the 17 by 17 area source grid. Thus, it was assumed that no integration tables would be necessary at distances greater than 61 km.

NHTS = 3
HINT(3) = 4.60, 9.10, 13.70
BPH = 6.85 and 11.40

The CDM 2.0 model (U.S. EPA, 1985c) was operated with the control options set to:

NGRAD = 0
FAC = 0.5
RCEPTZ = 0.0
NDEF = 1, the regulatory default option for urban area applications
DELR = 200
RAT = 2.5
CV = 1000

HL(1)-HL(6) = 2100, 1400, 1400, 1400, 1050, 700 with mean
values from Holzworth (1972) mixing height tables
U(1)-U(6) = 1.50, 2.46, 4.47, 6.93, 9.61, 12.52
XG = 464.5
YG = 4400
TOA = 12.6 from local climatological data (LCD) summary
TXX = 2500
DINT = 10

In contrast to dispersion models, the interactive nature of the CMB model does not facilitate the compilation of a list of parameters which are adjusted once and then remain in effect for an entire set of model executions. The adjustments made in the CMB model take the form of selecting the set of source profiles and chemical features which will be included in the mass balance regression calculation.

For the example urban area, the selection process was conducted in an iterative fashion by systematically adding and deleting sources and features from the calculation until a "best" fit solution was obtained. The determination of this fit was guided by a combination of summary statistics reported by the model together with the analyst's understanding of the airshed under consideration (see U.S. EPA, 1987d).

7.5 Comparison of Observed and Dispersion Modeled Concentrations

The model runs described in the previous section generated a large amount of data with which the performance of the dispersion models can be assessed with respect to the example urban area. In this section, the performance of the dispersion models is examined by comparing the model results with the PM_{10} concentrations derived from the TSP measurements. In Section 7.6, dispersion model performance is evaluated further by comparing the receptor and dispersion model results.

7.5.1 Annual Average Modeling

Table 7-1 shows the initial comparisons between the measured minus background and modeled PM_{10} concentrations predicted by CDM 2.0 and RAM in the example urban area. The table is based on the 17 selected TSP sites, and uses PM_{10} values derived from the measured TSP concentrations. CDM 2.0 comparisons are presented for four approaches to incorporating temporal variability into the emission inventory including: 1) seasonal and diurnal variability; 2) seasonal variability; 3) diurnal variability; and 4) constant inventory (i.e., no temporal resolution). Table 7-1 shows that on the basis of correlation coefficient, slope and intercept, CDM 2.0 performs reasonably well for all versions of temporally resolved inventories. However, all four sets of CDM 2.0 modeling results underpredict the observed PM_{10}. Seasonal variability is seen to have negligible influence on the predictions while diurnal variability provides the largest underpredictions. The lower predictions provided by the diurnally variable inventory are due to higher daytime emission rates coinciding with the higher daytime winds speeds which cause greater dilution and result in reductions in overall average concentrations. Despite the large underpredictions associated with the diurnally dependent emission inventories, diurnal variability was retained in the inventories for further annual average modeling because the concept is physically justified and was shown to have a significant influence on the modeling results.

7.5.2 Short-Term Modeling

The comparisons of RAM predicted and measured minus background PM_{10} concentrations shown in Table 7-1 indicate that the results of the RAM model, in general, follow the same trends exhibited by the CDM 2.0 model results. As was found for CDM 2.0, the RAM results underpredict the measured minus

TABLE 7-1

INITIAL CDM 2.0 AND RAM MODEL EVALUATION ANALYSIS RESULTS FOR THE 17 SELECTED SITES

Emission Rate Variability:	CDM 2.0				RAM				
	Seasonal, Diurnal	Seasonal	Diurnal	None	Seasonal, Daily, Hourly	Seasonal, Hourly	Seasonal	Hourly	None
Number of Samples (n)	17	17	17	17	956	956	956	956	956
Correlation (r)	.759	.764	.763	.767	.233	.181	.207	.257	.260
Slope (m)	.603	.678	.604	.685	.143	.105	.132	.134	.159
Intercept (b)	6.3	7.2	6.1	6.9	12.2	13.2	15.2	12.6	14.6
Avg. Background*	21	21	21	21	21	21	21	21	21
Avg. Measured-Background ($\mu g/m^3$)	26	26	26	26	26	26	26	26	26
Avg. Predicted ($\mu g/m^3$)	22	26	22	25	16	16	19	16	19
Avg. Max. Measured-Background ($\mu g/m^3$)	--	--	--	--	64	64	64	64	64
Avg. Max. Pred. ($\mu g/m^3$)	--	--	--	--	52	50	54	43	49
Avg. 2nd Max. Measured-Background ($\mu g/m^3$)	--	--	--	--	57	57	57	57	57
Avg. 2nd Max. Pred. ($\mu g/m^3$)	--	--	--	--	37	37	40	33	37
Avg. 1st-5th Max. Measured-Background ($\mu g/m^3$)	--	--	--	--	53	53	53	53	53
Avg. 1st-5th Max. Pred. ($\mu g/m^3$)	--	--	--	--	36	35	38	32	36

* Background Range: 5-44 $\mu g/m^3$

background concentrations, and hourly variability (which for RAM is in essence equivalent to diurnal variability for CDM 2.0) is the only characteristic of emission inventory variability which significantly influences the modeling results. Although the RAM results follow the same patterns as the CDM 2.0 results, the overall performance of RAM, as indicated by the correlation coefficients, slopes, intercepts and ratios of measured minus background to predicted PM_{10} concentrations, is much poorer than CDM 2.0. However, with short-term modeling, which is conducted in reference to the 24-hour average NAAQS, overall model performance is not as important as the ability to correctly predict elevated impacts. Furthermore, a short-term model must provide estimated concentrations which agree in magnitude and location with elevated observations. The lower right-hand corner of Table 7-1 summarizes the performance of the RAM model with respect to predicting elevated impacts. On average, the elevated RAM results greatly underpredict the measured elevated concentrations. However, the addition of temporal resolution to the inventory does not appear to influence the performance of RAM with respect to predicting elevated measured concentrations. Therefore, the development of a temporally variable emission inventory is not necessary for short-term modeling.

The RAM model evaluation analyses also revealed that the RAMMET processor program occasionally may produce unrealistically low mixing height estimates and subsequent overpredictions of area source impacts. Should this problem arise the EPA Regional Meteorologist should be consulted to develop appropriate corrective action.

In summary, the initial comparisons between modeled and observed PM_{10} concentrations show that CDM 2.0 and RAM underpredict the measured values for the example urban area. The largest relative underprediction was noted for the RAM model when measured minus background and predicted elevated concentrations were compared. In addition, temporal variability was shown to be important for annual average CDM 2.0 modeling but of negligible influence with respect to the significant indicators of RAM model performance. On the basis of the initial comparisons between predicted and measured minus background concentrations, a tentative conclusion was made that the underpredictions by both models were most probably due to misspecified emission rates in the inventory. In the next section, a more detailed understanding for the underpredictions is derived by comparing the receptor and dispersion model results.

7.6 Comparison of Receptor and Dispersion Model Results

The source contribution estimates provided by CMB and dispersion modeling generally are not easily compared in the formats generated by the models. To facilitate logical comparisons, the dispersion model results are usually regrouped. The regrouping proceeds by combining the impacts of point sources associated with similar processes and separating the area source impacts into their principal components on the basis of the emission inventory. For the example urban area, the regrouping process provided 14 source categories for comparing receptor and dispersion model results.

Table 7-2 shows the average receptor/dispersion model comparisons for three sites in the example urban area. The averages were formed from the same set of sampling periods for each of the sites. The RAM model was used to make the comparisons because, unlike CDM 2.0, RAM permitted the use of the meteorological conditions which were measured during the sampling periods selected for CMB analysis. However, any misspecifications in dispersion model input which are identified from the comparisons of RAM with CMB should be applicable to CDM 2.0 because both dispersion models rely on essentially the same assumptions and input data.

Table 7-2 shows several similarities between the results of the CMB and RAM models including: 1) reasonable agreement between RAM and CMB for many sources at all three sites; 2) an equal unexplained portion of the observed mass by both models; 3) reasonable agreement between background and secondary sulfate; and 4) excellent agreement between CMB and RAM for the impact of the antimony source at site A (see Figure 3-4) which is the site nearest to the source. Table 7-2 also shows several substantial differences between the results of the RAM and CMB models. These differences were examined and then reconciled following the eight-step procedure described in the Protocol for Reconciling Differences Among Receptor and Dispersion Models (U.S. EPA, 1987b). In the following discussion, the differences will be identified and their reconciliation summarized on a case-by-case basis.

Case 1: CMB estimates of the impact of crustal material are significantly greater than those predicted by RAM. What is the cause of the disagreement and how can the difference be reconciled?

A thorough review was conducted of the CMB modeling procedure and input data with respect to estimating crustal material contributions. The review indicated that the CMB model provided very reliable estimates of crustal material impacts. A review of the RAM model inputs identified two errors in the emission inventory which could have substantially influenced the crustal material impact estimates. The errors included: 1) the emission factor for construction activity was low by a factor of four; and 2) the emission factor used for unpaved road dust was low by a factor of two. The errors were then corrected and resulted in a 50 percent increase in the overall area source emissions.

Case 2: CMB estimates of the impact of coal combustion are significantly greater than those predicted by RAM. What is the cause of the disagreement and how can the difference be reconciled?

TABLE 7-2

INITIAL COMPARISONS OF THE AVERAGE RAM AND CMB MODEL RESULTS
(Contributions expressed as percents of the measured averages)

Source Type		Site A	Site B	Site F
Oil Combustion	RAM	.9	.6	.1
	CMB	.8	1.0	1.6
Coal Combustion	RAM	1.3	.1	.7
	CMB	5.9	1.3	1.0
Oil Refineries	RAM	.4	1.0	.08
	CMB	2.2	7.3	0
Incinerators	RAM	.2	.4	.05
	CMB	.3	1.0	2.5
Antimony Source	RAM	1.0	.1	.003
	CMB	1.4	.02	.03
Secondary Metals	RAM	.2	.03	.03
	CMB	1.0	1.3	.8
Iron & Steel	RAM	.2	.2	.2
	CMB	.02	.05	.08
Chem. Mfg.	RAM	.06	.1	.08
Other Point Sources	RAM	.5	.1	.6
Other Area Sources	RAM	6.0	3.5	5.0
Mineral Processing	RAM	.2	.1	.2
Road Dust & Soils	RAM	11.3	6.7	9.0
	CMB	19.	14.	23.
Mobile Sources	RAM	5.5	3.2	4.6
	CMB	3.2	3.3	3.8
Background	—	55.	63.	62.
Secondary SO_4	CMB	46.	49.	49.
Total (+ Background)	RAM	83.	80.	83.
Total	CMB	80.	77.	82.
Unexplained	RAM	17.	20.	18.
	CMB	20.	22.	19.

A review of the CMB parameters associated with coal combustion substantiated the coal combustion contribution estimates provided by the CMB model. Reviewing the RAM inputs related to coal combustion revealed two causes for the differences between CMB and RAM. First, several estimates were available for the emission rate for the largest coal combustion source in the airshed. In the RAM modeling, the lowest estimate of the emission rate had been employed. The inventory was changed to include the highest emission rate estimate for this source because RAM was underpredicting CMB and the CMB results had been judged to be reliable. Second, a portion of the difference between CMB and RAM was found to be an artifact of the method used to group the source contributions for comparisons and not a problem with one of the modeling approaches. Specifically, the impacts from residential coal combustion emissions were reported as part of the "other area sources" category in Table 7-2.

Case 3: At sites A and B (see Figure 3-3), there are several sampling periods for which CMB and RAM predicted elevated impacts from oil refineries. For these periods, the CMB estimates are much greater than the RAM estimates. What are the causes of the disagreements and how can the differences be reconciled?

A review of the CMB parameters associated with refineries revealed that the source composition profile associated with refineries lacked any distinguishing features which resulted in a high detection limit for the CMB model in terms of estimating refinery impacts. Because of the high detection limit, the CMB estimates of refinery contributions were re-examined in detail for each site and sampling period combination. With one exception, the CMB results were found to be consistent with the supporting data. The one exception was a high impact which was estimated for one sampling period at site B. An error was found in the modeling procedure used for this sample and therefore the CMB model was re-run for the sample using the correct modeling procedure.

Because the remaining CMB estimates were shown to be valid, the reconciliation process shifted focus to examining the RAM input data related to oil refineries. Seven major refineries were identified in the emission inventory. Only two of these were located upwind during the periods for which CMB and RAM predicted elevated impacts. As was found to be true for the coal combustion source, several emission rate estimates existed for each of the two upwind refineries. Once again, the low end of the emission rate scale had been used in the evaluation modeling. Because RAM was underestimating CMB, the emission inventory was adjusted to include the higher emission rate estimates for the two refineries.

Case 4: There was reasonably good overall agreement between CMB and RAM for the incinerator source category. However, for some of the sampling periods at site F (see Figure 3-3), the CMB model predicted significant contributions from incinerators while the RAM model results showed impacts close to zero. What are the causes of the disagreements and how can the differences be reconciled?

A thorough review of the CMB input data showed the incinerator impact estimates to be very reliable due to the highly distinctive source profile associated with incinerator emissions. Next, the RAM input data were reviewed and three major incinerators were identified. The emission rates in the inventory corresponded well with the capacities and operating conditions of the plants. This agrees with the fact that the CMB and RAM results were in reasonable agreement when known incinerators were upwind of the monitoring sites. However, the CMB model also predicted significant impacts at site F from incineration during periods when none of the inventoried sources were upwind of the site. Therefore, the conclusion was made that during these periods, incinerators not in the inventory were responsible for the impacts estimated by the CMB model. This implied that the contributing incinerators were either outside the area covered by the inventory or else within the inventoried territory but absent from the inventory. This matter was not pursued further for the example urban area. In the case of a real SIP development, a more definitive resolution would be required. For this study, the incinerator emission rates were left unchanged because the available evidence did not justify any alterations which would have brought CMB and RAM into closer agreement.

7.7 Comparison of Observed Concentrations to Final Dispersion Model Results

Following reconciliation of the RAM and CMB modeling results, selected RAM and CDM 2.0 model evaluation analyses were repeated using the revised source emission rates obtained during the reconciliation process. Table 7-3 shows the results of the post-reconciliation evaluation analyses and provides comparisons with the initial evaluation analysis results which were originally discussed in Section 7.5. The left-hand side of Table 7-3 shows that the revised inventory produced little overall improvement in the performance of the CDM 2.0 model. The most significant change is the replacement of the previous underprediction with an overprediction of approximately equivalent magnitude (~5 $\mu g/m^3$) suggesting that the revised inventories contained increases that were too large. The right-hand side of Table 7-3 shows a substantial improvement in RAM model performance due to the inventory revisions. Much better agreement now exists between the predicted and measured minus background combined-site average PM_{10} concentrations. More importantly, there is now excellent agreement between the RAM model-predicted and the measured minus background concentrations for the short-term averages which are critical to the development of reliable control strategies for the 24-hour NAAQS.

In summary, the model evaluation analyses demonstrated that the receptor/dispersion model reconciliation process improved the performance of the dispersion models. Although CDM 2.0 overpredicts, RAM provides excellent

TABLE 7-3

FINAL CDM 2.0 AND RAM MODEL EVALUATION ANALYSIS RESULTS FOR THE 17 SELECTED SITES

	CDM 2.0		RAM	
	Initial	Final	Initial	Final
Number of Samples (n)	17	17	956	956
Correlation (r)	.763	.736	.260	.259
Slope (m)	.603	.820	.159	.225
Intercept (b)	6.1	10.0	14.6	21.3
Avg. Background*	21	21	21	21
Avg. Measured-Background (μg/m^3)	26	26	26	26
Avg. Predicted (μg/m^3)	22	32	19	27
Avg. Max. Measured-Background (μg/m^3)	—	—	64	64
Avg. Max. Pred. (μg/m^3)	—	—	52	69
Avg. 2nd Max. Measured-Background (μg/m^3)	—	—	57	57
Avg. 2nd Max. Pred. (μg/m^3)	—	—	37	53
Avg. 1st-5th Max. Measured-Background (μg/m^3)	—	—	53	53
Avg. 1st-5th Max. Pred. (μg/m^3)	—	—	36	49

* Background Range: 5-44 μg/m^3

agreement with measured minus background concentrations using the same emission inventory. This difference in model performance must be ascribed to the different model algorithms rather than the emission inventory. When the post-reconciliation CDM 2.0 and RAM model evaluation analyses are considered together, further changes to the emission inventory are neither justified nor necessary. For the annual average control strategy modeling, the predicted impacts were calibrated using the procedures described in the CDM 2.0 User's Guide (U.S. EPA, 1985c) and the regression coefficients in Table 7-2 to ensure that future annual impacts are not overpredicted.

8.0 CONTROL STRATEGY EVALUATIONS FOR THE EXAMPLE URBAN AREA

8.1 Overview of the Design Concentration Concept

Control strategy development is the process of preparing a verifiable plan showing the level of control needed to demonstrate attainment of the PM_{10} NAAQS. The concept of design concentrations assumes a central role in control strategy development. A design concentration is that PM_{10} concentration which a control strategy must be capable of reducing to the level of the appropriate NAAQS. In other words, design concentrations function as the basis or reference point from which the necessary level of controls are determined. Therefore, the process of control strategy development begins with determining appropriate design concentrations.

PM_{10} control strategies must address the 24-hour and annual average PM_{10} NAAQS. Therefore, two sets of design concentrations must be established for receptors which show a high probability of nonattainment with respect to the 24-hour and annual average NAAQS. Emission limits must be set to provide for the attainment of both standards. This is accomplished by developing a control strategy on the basis of the standard which produces the more stringent emission limits. In general, a confident assessment of which standard will provide the stricter limitations cannot be made prior to control strategy testing. In these cases, a reasonable procedure is to make a systematic assessment as to which standard is more restrictive and design the control strategy with reference to that standard. Next, the control strategy is evaluated in terms of providing for demonstrable attainment of both NAAQS. If attainment of both standards is demonstrated, then the correct NAAQS was used as the basis for control strategy development.

Ambient measurements or model estimates may be employed to determine design concentrations. If model estimates are used, the design concentration is taken as the sum of the modeled source impacts plus the background.

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Development of the annual average design concentration is relatively straightforward. If one or more years of ambient PM_{10} measurements are available for a site, the design concentration is the average of the observed annual averages. Similarly, if one or more years of annual average PM_{10} modeling have been performed, the design concentration is simply the average of the annual averages.

In contrast to the annual average case, establishing a design concentration which is appropriate for the 24-hour NAAQS can be considerably more complicated. The complications arise from the statistical nature of the 24-hour NAAQS which limits the expected number of exceedances of the NAAQS to one or less per year. The PM_{10} SIP Development Guideline (U.S. EPA, 1987a) gives four procedures for calculating 24-hour design concentrations including: 1) table look-up; 2) projections from statistical distributions; 3) graphical estimation; and 4) conditional probabilities. For further details on the four procedures see the PM_{10} SIP Development Guideline (U.S. EPA, 1987a).

Following the PM_{10} SIP Development Guideline (U.S. EPA, 1987a), the design concentrations for the example urban area were determined from the results of dispersion model simulations performed with five years of meteorological data. The average of the CDM 2.0-produced annual averages for each of the five meteorological years was used for the annual average design concentration at each modeled receptor. The table look-up procedure was applied to the results of 1827 individual days modeled by RAM to determine the 24-hour design concentrations. Since the model provided a continual record of the PM_{10} concentrations for five years, the design concentration for each receptor was simply the sixth highest modeled plus background PM_{10} concentration at each receptor.

8.2 Establishing Baseline and Projected Emissions

Precise determination of baseline and projected emissions is critical to developing a defensible control strategy. Baseline emissions are the current emission levels of the sources within the geographical area covered by the control strategy. Projected emissions refer to expected future emission levels. Three types of sources are of importance in developing emission projections; 1) existing regulated sources which are currently emitting significantly below allowable levels; 2) new major regulated sources; and 3) unregulated sources whose emission levels may change in response to general economic development and/or population growth.

Detailed information on forecasting techniques applicable to developing emission projections is contained in the Guidelines for Air Quality Maintenance Planning and Analysis, Volume 7: Projecting County Emissions (U.S. EPA, 1975).

For the example urban area, maximum allowable emissions and appropriate growth factors were employed to develop a projected emission inventory for future years. No new major sources were included in the inventory.

8.3 Preparation of Dispersion Model Input Data for the Example Urban Area

Emissions, meteorological and receptor data sets were prepared for use in the dispersion model analyses required for control strategy development. Input data were prepared for both the RAM and CDM 2.0 models. Three different data sets were prepared for input to RAM. These data sets were prepared for use in analyses designed to identify the most cost-effective and reliable method of using RAM in control strategy development. The preparation of the three types of model input data required for RAM and CDM 2.0 is described below.

8.3.1 Emissions Data

The emission inventory used for the RAM and CDM 2.0 control strategy modeling was the projected inventory described above. For RAM, that inventory contained temporally constant emission rates for all 261 point and 289 area sources. For one of the RAM data sets, a smaller point source inventory was created by combining similar collocated point sources. Similar sources were defined as those sources with similar stack heights and plume buoyancies as determined by calculating their "K" values as follows (U.S. EPA, 1973):

$$K = (H * T * V)/Q \qquad (8-1)$$

where:

H = stack height
T = exhaust gas temperature
V = exhaust gas flow rate
Q = emission rate

Similar sources were then modeled as one source using the stack parameters of the original source with the lowest "K" value and the sum of the emissions from each original source. This reduced the number of point sources from 261 to 144.

For CDM 2.0, diurnal emission rate variability was simulated for all sources through the use of the input parameters YD and YN, which were set to 1.28 and 0.8, respectively, based on the temporal variability of the emissions in the inventory.

8.3.2 Meteorological Data

Two sets of meteorological data were prepared for the control strategy modeling with RAM. The first data set contained 36 days of hypothetical meteorological data. For each day, each hour of data represented one of the critical combinations of wind speed and atmospheric stability conditions commonly used in screening dispersion modeling (U.S. EPA, 1981c). The 24 combinations of hourly wind speed and atmospheric stability conditions used for each day follow:

Wind Speed (m/s)	Pasquill/Gifford Atmospheric Stability Class
1	A,B,C,D,E,F
3	A,B,C,D,E,F
5	B,C,D,E,F
7	C,D
10	C,D
15	C,D
20	D

Each of the 36 days of hypothetical meteorological data was assigned a different wind direction (which was then used for all the hours in the given day). The wind direction for each day differed in 10 degree increments. For each hour of each day, the ambient temperature was set to 293 degrees Kelvin and the mixing height was set to 500 meters.

The second set of meteorological data needed for the control strategy modeling with RAM was the hourly data from 1980 to 1984. The five years of data were prepared for model input using the RAMMET processor program.

Separate files of STAR data were developed for each of the five years (1980-1984) and were then used for the CDM 2.0 control strategy modeling analyses. These files were created by applying appropriate software to the corresponding years of RAM format hourly data.

8.3.3 Receptors

The selection of appropriate receptor locations is critical to control strategy development modeling. Receptors are needed wherever there is the potential for PM_{10} nonattainment. Receptor grids of varying densities can be used to determine the location and boundaries of nonattainment areas.

However, multisource modeling for large receptor grids is expensive. For the example urban area, a more efficient approach was developed to identify locations with the greatest potential for PM_{10} nonattainment. The approach involved applying the EPA procedures designed for estimating the probability of PM_{10} nonattainment (U.S. EPA, 1986a) to the 1982 to 1984 TSP data recorded at the 17 TSP monitoring sites located within the 42.5 by 42.5 km area source grid. This process produced a 95 percent probability of nonattainment at 3 monitoring sites (9, 14 and 17 in Figure 3-4) and a 20 to 95 percent probability of nonattainment at 5 monitoring sites (4, 5, 7, 10 and 16 in Figure 3-4). A receptor grid with 2 km spacing was then placed around these 8 monitoring sites, and these receptors (a total of 74) were used in the initial input for the CDM 2.0 control strategy modeling. (Initially, 1 km spacing was employed, but the spatial variation in modeled concentrations was negligible, primarily because the area sources were modeled as 2.5 km squares.)

8.4 Derivation of Background Concentrations

The background concentrations needed for control strategy development differ somewhat from those needed for dispersion model evaluation. For model evaluation, background values were needed for the specific days being modeled. In contrast, the background concentrations needed for control strategy development must be reasonable estimates of concentrations that may occur in the future. For an annual standard, the future concentrations should represent an average year, but for the 24-hour standard the future concentrations should represent maximum concentrations that may occur on any given day. This section describes the derivation of such estimates for the example study area.

There are a number of available methods for determining PM_{10} background concentrations. Several are described in the Guideline on Air Quality Models (Revised) (U.S. EPA 1986b) and in Appendix D of the PM_{10} SIP Development Guideline (U.S. EPA, 1987a). For the example urban area, the background concentration estimates used in the model evaluation analyses were based on the average concentrations observed from among a set of upwind monitoring sites identified as background sites.

In the model evaluation analyses referred to above, 24-hour average TSP background concentrations were determined on the basis of the TSP sampling conducted in 1982 at the set of 12 background sites. The appropriate average concentration recorded within the upwind subset of the 12 sites was used as the 24-hour average TSP background concentration. In order to derive PM_{10} background concentrations for control strategy development, this process was repeated using 1980, 1981, 1983 and 1984 TSP data at the same set of 12 designated background sites. For each year, this procedure produced sets of 61 24-hour average TSP background concentrations. The resulting 305 values provide a detailed set of estimates of 24-hour average TSP background concentrations under a variety of meteorological conditions. The maximum value in this data set provides a good estimate of the maximum future 24-hour average TSP background concentration and the average of all the values provides an estimate of the annual average TSP background concentration.

The procedure described above produced maximum 24-hour and annual average TSP background concentrations of 85 and 31.3 $\mu g/m^3$, respectively. PM_{10} background concentrations were then obtained by assuming that the 0.8 PM_{10}/TSP concentration ratio observed in the study area also applies to background. Applying this assumption yields maximum 24-hour and annual average PM_{10} background concentrations of 68 and 25.0 $\mu g/m^3$, respectively.

8.5 Modeling Projected Source Emissions

The next task in control strategy development was modeling using the projected source emissions to determine the location, degree and spatial extent of future nonattainment in the example urban area. The primary objective of the modeling was to determine the design concentrations that must be reduced below the NAAQS level. Another objective was to confirm that the EPA procedures for estimating the probability of PM_{10} nonattainment can be used to identify nonattainment area locations. A third objective was establishing the NAAQS exceedance boundaries. The CDM 2.0 and RAM modeling performed to meet these objectives is described below.

8.5.1 Modeling for the Annual Average NAAQS

Annual average modeling was performed using CDM 2.0 and the data input described in Section 8.3. All 550 sources were modeled using the projected emissions (with diurnal variability) of the post-reconciliation inventory. Modeling was performed separately using each of the five years of STAR meteorological data. The 1982 STAR data were used first to calculate concentrations at the 74 receptors selected previously (see Section 8.3.3). Additional receptors (2 km spacing) were then added near any receptors where concentrations in excess of the NAAQS were indicated. The modeling and adding of receptors was continued using the other four years of STAR data to establish the boundaries of the NAAQS exceedance area. In two areas where point sources produced significant impact gradients, other receptors (1 km spacing) were also added as necessary to obtain better estimates of maximum concentrations. The concentrations from the five modeled years were averaged to determine the attainment status of each receptor.

The average results from the five years of CDM 2.0 modeling analyses are shown in Figure 8-1. The figure shows the complete grid of 107 receptors and the average modeled PM_{10} concentrations corrected for the overprediction bias noted in the CDM 2.0 model evaluation analyses (see Section 7.7). The corrected values were obtained by applying the final CDM 2.0 slope and intercept values shown in Table 7-3 to the modeled PM_{10} concentrations.

In order to achieve compliance with the annual PM_{10} NAAQS, all the concentrations at the receptors in Figure 8-1 must be reduced to less than 25 $\mu g/m^3$ (the difference between the 50 $\mu g/m^3$ annual NAAQS and the 25 $\mu g/m^3$ background concentration). The isopleth line shows the boundaries of the annual average PM_{10} exceedance area. There are four hot spot receptors where the annual average PM_{10} concentrations reach maximum levels. The four hot spot receptors are located in the northeast (36 $\mu g/m^3$), center (39 $\mu g/m^3$), upper southern (59 $\mu g/m^3$), and lower southern (70 $\mu g/m^3$) areas of the grid. To make this example task more manageable, it was hypothesized that control strategies which result in the NAAQS being attained at the four hot spot receptors will also produce attainment at all the other exceedance area receptors. The four hot spot concentrations plus background were therefore established as the design concentrations for the annual average PM_{10} NAAQS.

8.5.2 Modeling for the 24-Hour NAAQS

For typical AQCR's, the use of refined short-term dispersion models to define design concentrations appropriate for the 24-hour NAAQS is potentially a very expensive process. The high costs are produced by the large number of computations needed to perform a comprehensive determination of the maximum predicted 24-hour PM_{10} concentrations at many receptors throughout the example urban area. For example, a comprehensive analysis of only a portion

Open rectangles enclose hot spot receptors.
Solid squares indicate monitoring sites.

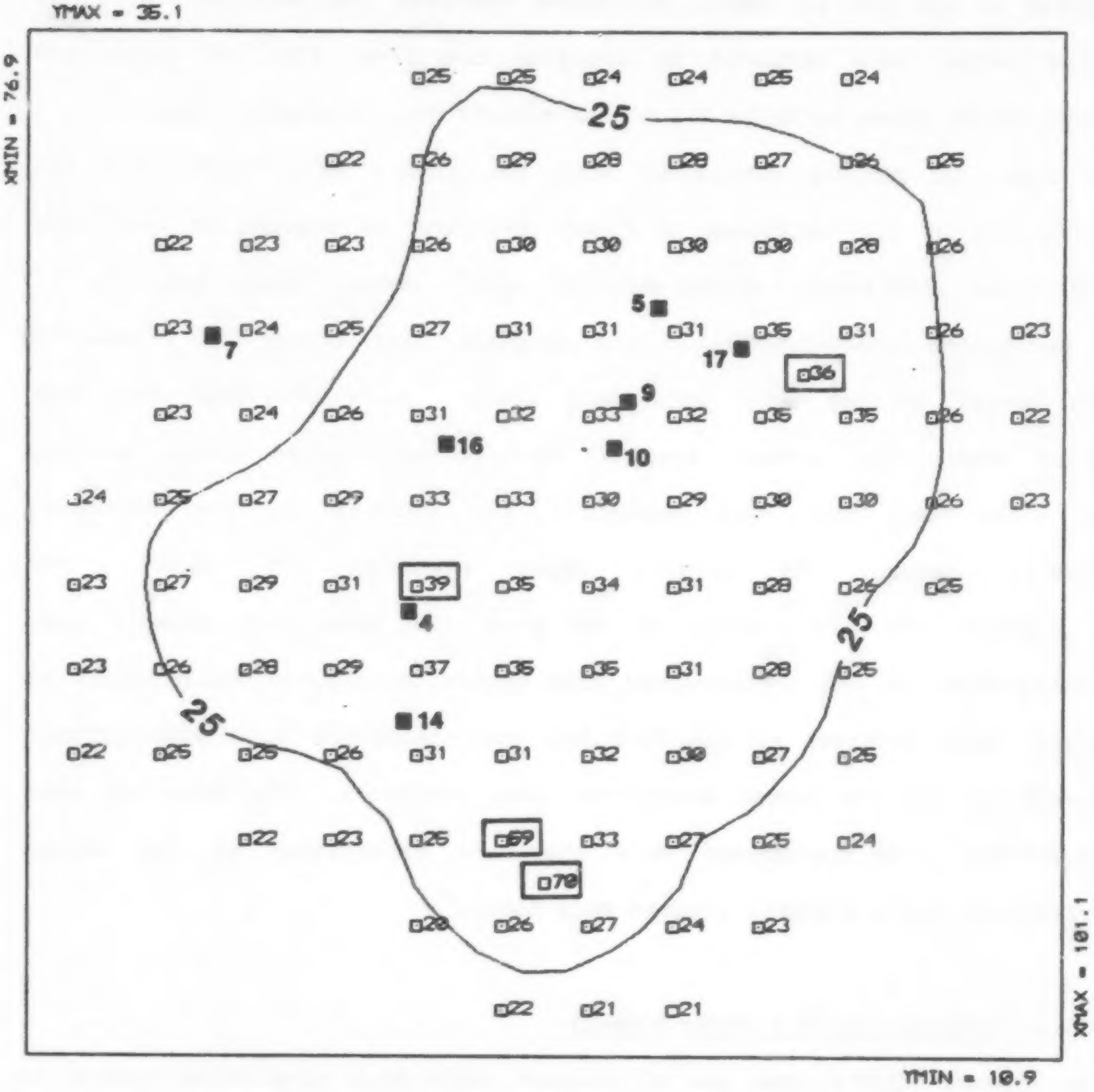


Figure 8-1. Corrected 5-year average CDM 2.0-modeled PM_{10} concentrations (µg/m³).

of the example urban area would require the calculation of 2.6×10^9 hourly concentrations. This estimate is based on five years (43,800 hours) of RAM modeling for 550 sources and 107 receptors. In general, only a minute fraction of these predicted concentrations will exceed the NAAQS. Therefore, a modeling approach which identifies the elevated predicted concentrations as reliably as a comprehensive analysis but in a more computationally efficient manner, has the potential for providing substantial cost reductions. Any such efficiency modeling approach would have to rely on some subset or sample of the populations of 43,800 hours, 550 sources and 107 receptors.

Two general types of sampling could be applied to form a subset of the hours, sources and receptors populations; probability sampling and directed sampling. Probability sampling is best suited for determining typical or average properties of a distribution. However, identifying the elevated concentrations is a search for outliers or the upper tail of a distribution and therefore, probability sampling is an inappropriate basis on which to design an efficiency modeling approach. On the other hand, directed sampling does have considerable potential with respect to efficiently defining the elevated concentrations. Therefore, a directed modeling efficiency analysis was developed, tested and used for the example urban area.

The RAM model efficiency analysis was performed in four steps (see Figure 8-2). The objectives of the first three steps were to 1) identify potential receptors in excess of the NAAQS, 2) identify critical days of meteorological data, 3) define NAAQS exceedance area boundaries and establish design concentrations.

In the first step of this analysis, the full inventory of 550 sources was modeled using the 36 days of hypothetical meteorological data described in Section 8.3.2. The model results provided maximum 1-hour average concentrations at a grid of 95 receptors which were selected because they were

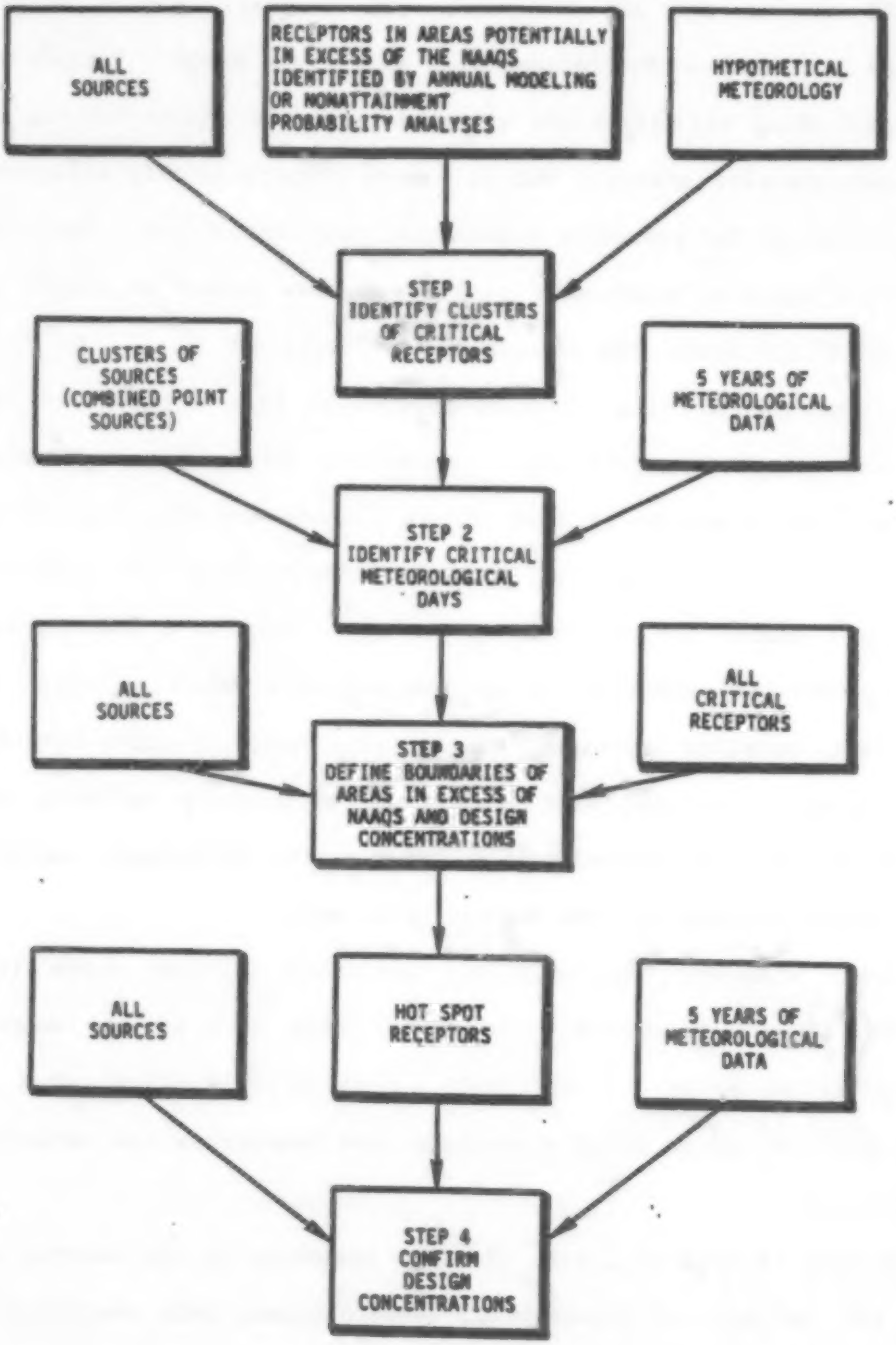

ALL SOURCES
RECEPTORS IN AREAS POTENTIALLY IN EXCESS OF THE NAAQS IDENTIFIED BY ANNUAL MODELING OR NONATTAINMENT PROBABILITY ANALYSES
HYPOTHETICAL METEOROLOGY
STEP 1 IDENTIFY CLUSTERS OF CRITICAL RECEPTORS
CLUSTERS OF SOURCES (COMBINED POINT SOURCES)
5 YEARS OF METEOROLOGICAL DATA
STEP 2 IDENTIFY CRITICAL METEOROLOGICAL DAYS
ALL SOURCES
ALL CRITICAL RECEPTORS
STEP 3 DEFINE BOUNDARIES OF AREAS IN EXCESS OF NAAQS AND DESIGN CONCENTRATIONS
ALL SOURCES
HOT SPOT RECEPTORS
5 YEARS OF METEOROLOGICAL DATA
STEP 4 CONFIRM DESIGN CONCENTRATIONS

Figure 8-2. Directed Modeling Approach for 24-Hour Average Design Concentrations.

within or near the area predicted by CDM 2.0 to be in excees of the NAAQS. Estimates of maximum 24-hour average concentrations were then obtained by multiplying the maximum 1-hour average concentrations by a factor of 0.4 (U.S. EPA, 1981c).

Based on an NAAQS of 150 µg/m^3 and the maximum 24-hour average background concentration of 68 µg/m^3, potential nonattainment areas may exist wherever 24-hour average modeled impacts exceed 82 µg/m^3. Potential receptors in excess of the NAAQS were therefore defined as those receptors where the maximum 1-hour average concentrations exceeded 205 µg/m^3 (82/0.4). Based on these assumptions, the initial RAM analysis results were used to identify areas where additional receptors were needed to establish the boundaries of the potential nonattainment area. A total of 38 such receptors were required to complete the RAM modeling with hypothetical meteorological data.

The results of Step 1, the hypothetical meteorological data modeling, are shown in Figure 8-3. The figure shows the entire 133 receptor grid and the maximum 1-hour average impact at each receptor. The figure also shows an isopleth line depicting the areas where a 150 µg/m^3 24-hour average PM_{10} NAAQS may be exceeded. In Figure 8-3, there are three hot spot areas where maximum 1-hour average PM_{10} concentrations are predicted to occur. These three areas are the same as those predicted by the CDM 2.0 modeling analysis (northeast, central, and southern hot spot areas).

The second step in the RAM model efficiency analysis focused on the three hot spot areas discussed above. Within each of these areas, a cluster of approximately 20 receptors was selected for further RAM modeling. For each cluster of receptors, the 25 combined point and 25 area sources with the greatest impact potential within the cluster were identified. For the combined point sources, impact potential was determined as a function of

Open rectangles enclose hot spot receptors.
Solid squares indicate monitoring sites.

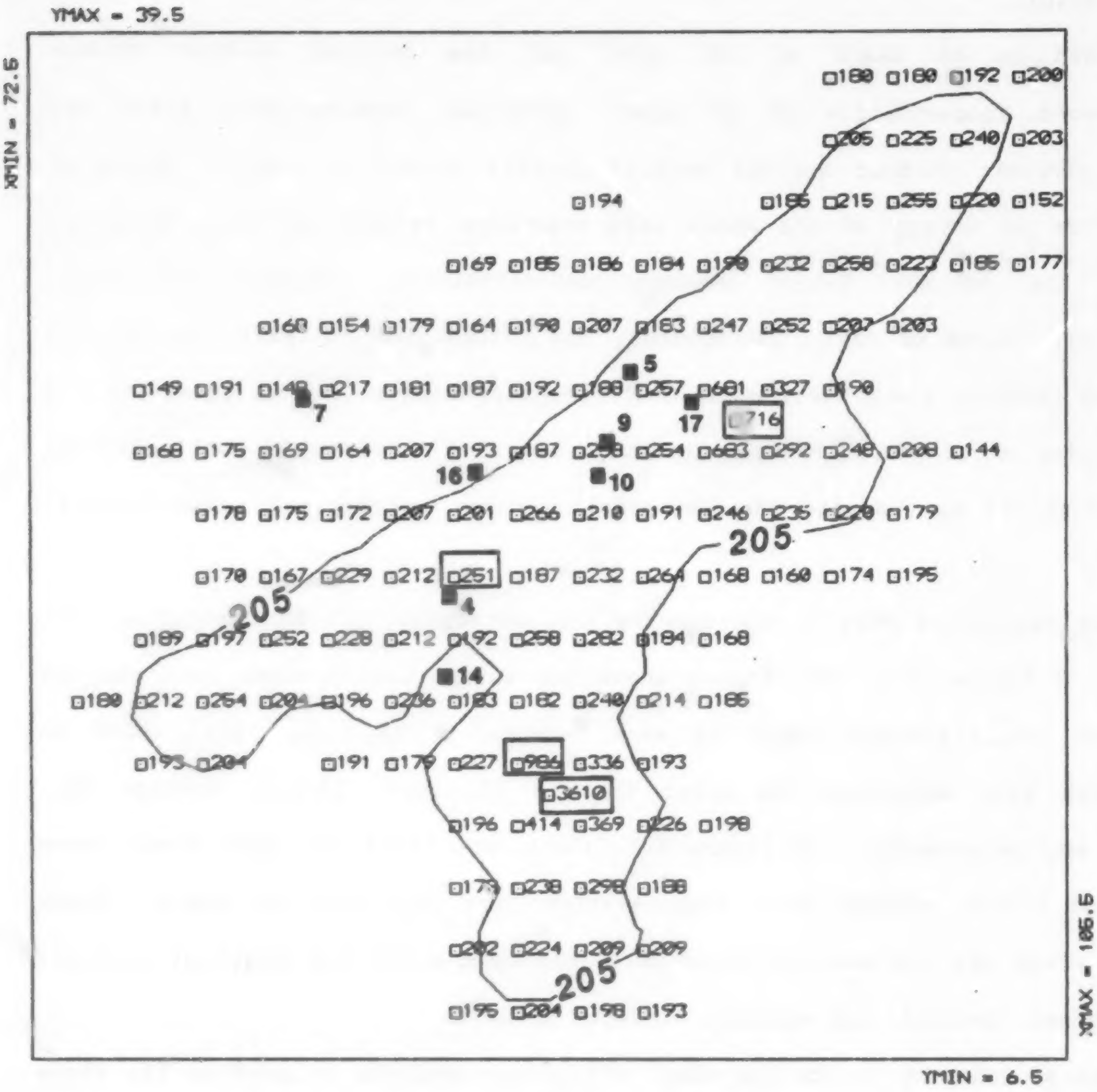


Figure 8-3. Maximum 1-hour average RAM-modeled PM_{10} concentrations produced using hypothetical meteorological data ($\mu g/m^3$).

emission rate, distance from the receptor and stack height. The selected area sources were those enveloping or nearest the receptors. RAM modeling analyses were then performed for each of the three groups of sources and receptors using all five years of meteorological data. Based on these analyses, the 120 days that produced any of the five highest modeled 24-hour average PM_{10} concentrations were defined as critical days of meteorological data.

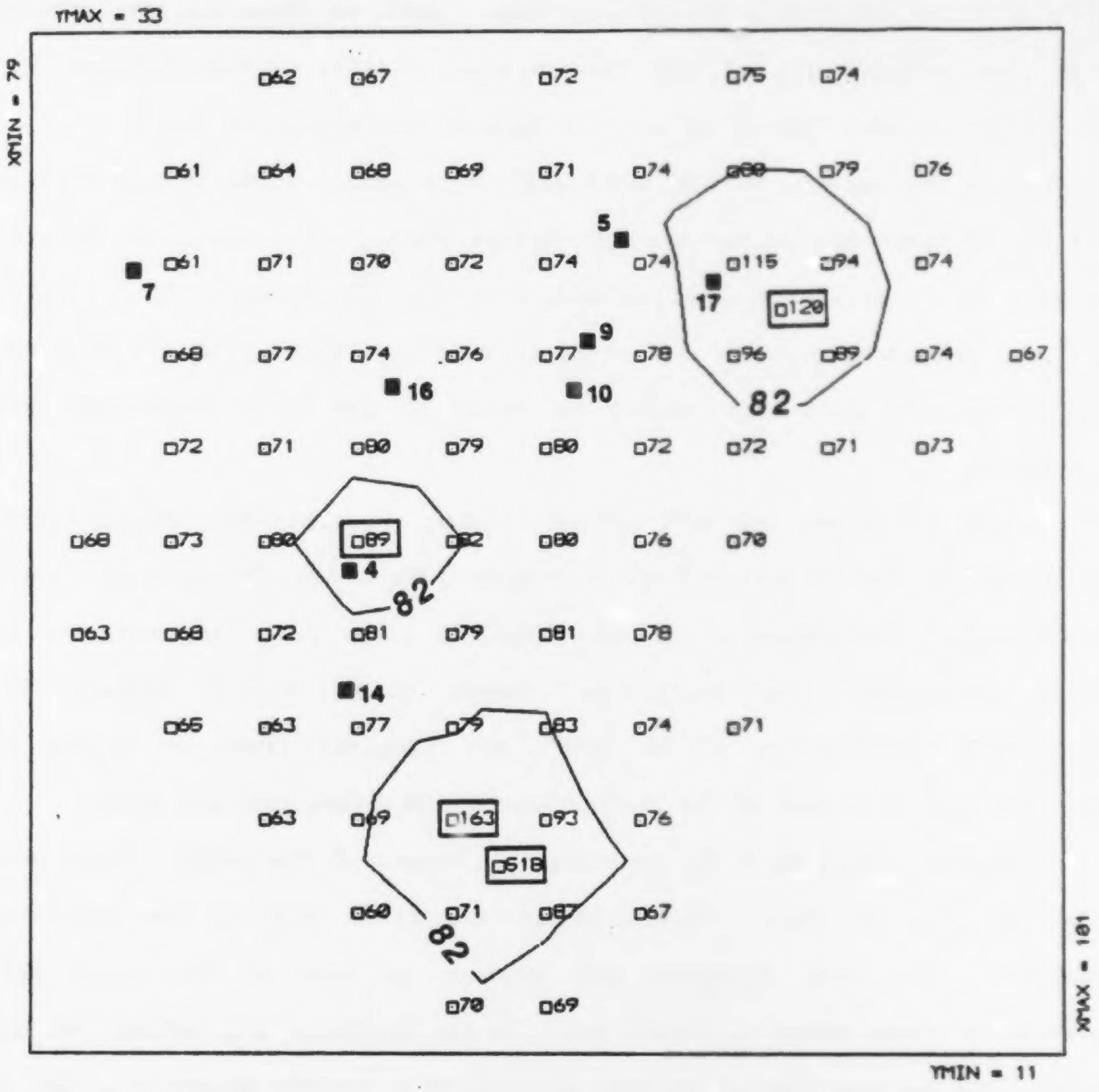
The third step of the RAM model efficiency analysis was performed using the 120 critical days of meteorological data identified in the first two steps as well as a limited number of receptors and all 550 sources. The receptors included the three clusters of receptors discussed above plus an additional 15, which were placed as needed to establish the NAAQS exceedance area boundaries.

Figure 8-4 shows the 6th highest 24-hour average PM_{10} concentrations calculated by RAM at the grid of 77 receptors using the 120 critical days of meteorology. The figure also shows isopleth lines drawn to represent the NAAQS exceedance area boundaries. Based on a 24-hour average PM_{10} background concentration of 68 $\mu g/m^3$, the isopleth lines on Figure 8-4 show the spatial extent of the 24-hour average PM_{10} nonattainment areas.

Figure 8-4 shows three hot spot areas in excess of the NAAQS. These areas are the same as those identified in the first step of the efficiency analyses. Hot spot receptors are evident in each of the three NAAQS exceedance areas shown in Figure 8-4. In the northeast and central hot spot areas, the maximum modeled 24-hour average PM_{10} concentrations are 120 and 89 $\mu g/m^3$, respectively. In the southern hot spot area, two maximum concentrations, 163 and 518 $\mu g/m^3$ are apparent.

To evaluate the reliability of the directed modeling efficiency analysis, a comprehensive analysis was conducted using the RAM model to calculate concentrations at the 40 receptors within and surrounding the three hot spot

Open rectangles enclose hot spot receptors.
Solid squares indicate monitoring sites.


YMAX = 33
XMIN = 79
XMAX = 101
YMIN = 11
62
67
72
75
74
61
64
68
69
71
74
80
79
76
5
7
61
71
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76
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82
63
68
72
81
79
81
78
14
65
63
77
79
83
74
71
63
69
163
93
76
618
60
71
87
67
82
70
69

Figure 8-4. Sixth highest 24-hour average RAM-modeled PM_{10} concentrations produced by 120 critical days of meteorological data which were selected by modeling source groups and receptor clusters (μg/m³).

areas shown in Figure 8-4. This modeling was performed using all five years of meteorological data and all 550 sources. The comprehensive analysis confirmed the boundaries of the NAAQS exceedance area produced by the directed modeling approach and the magnitude of the sixth-highest concentrations at three of the four hot spots shown in Figure 8-4. A larger sixth-highest concentration was obtained only at the northeast hot spot receptor, and its value was 126 $\mu g/m^3$ versus the 120 $\mu g/m^3$ calculated previously. Therefore, the directed modeling approach produced definitive estimates of the NAAQS exceedance area boundaries and the maximum locations of the concentrations needed as design concentrations for the 24-hour average PM_{10} NAAQS. Since the first three steps in the directed modeling approach slightly underestimated the sixth highest concentration at one of the four hot spot receptors, the final step in any directed modeling analysis must be the confirmation of the design concentrations at the individual hot spot monitors using all five years of meteorological data.

On the assumption that emission reductions which produce concentrations at or below the NAAQS at the hot spots will also produce attainment at all other receptors, the four hot spot concentrations plus background were assigned as the design concentrations for the 24-hour average PM_{10} NAAQS.

8.6 Control Strategy Selection

The design concentrations developed in the previous section indicate that there is a PM_{10} nonattainment problem for both the 24-hour and annual averaging periods. Integrated planning is required to develop control strategies with respect to the two averaging periods. As discussed previously, the controlling standard is that standard for which the greater emission reductions are required. The controlling standard cannot be reliably established until control strategy testing is performed. However, for the purpose of control strategy development, a tentative determination of the controlling standard was obtained by compiling source contribution listings for each averaging period at the four critical receptors. Based on these listings, proposed control strategies were derived by focusing on the sources and source groups with the largest percentage impacts and greatest potential for emission reduction.

Tables 8-1 to 8-4 present the annual and 24-hour average PM_{10} source contributions, proposed controls, and controlled contributions for the four critical receptors identified in the example urban area. Table 8-1 pertains to the northeast hot spot receptor and shows that nearby area sources and a coke production plant are the largest contributors to the annual and 24-hour nonattainment problems at this site. The table demonstrates that the controls required to achieve compliance with the annual standard equal or exceed those required for the 24-hour standard. Therefore, the annual standard governs the controls required at the northeast hot spot receptor. The proposed control strategy includes emission reductions of 75 percent at the coke plant and 25 percent for area sources. The proposed area source emission reductions could be provided by implementing a variety of control measures including 1) street sweeping; 2) limiting track-out from construction sites; and 3) paving frequently traveled unpaved roads.

Table 8-2 shows that nearby area sources are primarily responsible for the annual and 24-hour concentrations in excess of the NAAQS at the center hot spot receptor and that as above, the annual standard dictates the level of required controls. Most of the area sources will require the same 25 percent emission reduction as was needed for the northeast hot spot receptor with the exception of area source 145 which surrounds the center receptor. For this area source, a 60 percent reduction in impact is required. While attempting to develop control measures to achieve this large reduction, three unusual

TABLE 8-1

PM$_{10}$ SOURCE CONTRIBUTIONS TO THE ANNUAL AND 24-HOUR AVERAGE DESIGN CONCENTRATIONS, AND PROPOSED CONTROL STRATEGIES FOR THE NORTHEAST HOT SPOT RECEPTOR

		CDM 2.0 5-Year Average			RAM Sixth-Highest 24-Hour Average		
Source Types	Source Numbers	Calibrated Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)	Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)
Background	--	25	--	25	68	--	68
Point	231[^]	5.1	75%	1.3	35	60%	14
	233[^]	--	--	--	4	--	4
	234[^]	2.9	75%	0.7	20	60%	8
	Other	4.5	None	4.5	7	None	7
	Subtotal	12.5	--	6.5	66	--	33
Area	181	0.8	25%	0.6	--	--	--
	182	1.4	25%	1.1	--	--	--
	183	4.7	25%	3.5	6	25%	5
	199	1.6	25%	1.2	9	25%	7
	200	1.1	25%	0.8	1	25%	0
	Other	14.1	25%	10.1	44	25%	33
	Subtotal	23.7	25%	17.3	60	25%	45
All		61.2	--	48.8	194	--	146

[^] Coke Production

TABLE 8-2

PM$_{10}$ SOURCE CONTRIBUTIONS TO THE ANNUAL AND 24-HOUR AVERAGE DESIGN CONCENTRATIONS, AND PROPOSED CONTROL STRATEGIES FOR THE CENTER HOT SPOT RECEPTOR

		CDM 2.0 5-Year Average			RAM Sixth-Highest 24-Hour Average		
Source Types	Source Numbers	Calibrated Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)	Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)
Background	--	25.0	--	25.0	68	--	68
Point	All	3.9	None	3.9	21	None	21
Area	127	--	--	--	4	25%	3
	144	1.5	25%	1.1	6	25%	5
	145	15.7	60%	6.3	37	25%	28
	146	1.0	25%	0.8	--	--	--
	161	0.9	25%	0.7	--	--	--
	162	2.8	25%	2.1	--	--	--
	Other	13.4	25%	10.1	21	25%	16
	Subtotal.	35.3	25%	21.1	68	25%	52
All		64.2	--	50.0	157	--	141

TABLE 8-3

PM$_{10}$ SOURCE CONTRIBUTIONS TO THE ANNUAL AND 24-HOUR AVERAGE DESIGN CONCENTRATIONS, AND PROPOSED CONTROL STRATEGIES FOR THE UPPER SOUTHERN HOT SPOT RECEPTOR

		CDM 2.0 5-Year Average			RAM Sixth-Highest 24-Hour Average		
Source Types	Source Numbers	Calibrated Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)	Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)
Background	--	25	--	25	68	--	68
Point	246[A]	16.5	96%	0.7	74	60%	30
	247[A]	15.9	96%	0.6	70	60%	28
	Other	6.8	None	6.8	6	--	6
	Subtotal	39.2	--	8.1	150	--	64
Area	95	--	--	--	3	25%	3
	111	1.1	25%	0.8	--	--	--
	112	3.7	25%	2.8	6	25%	4
	128	0.9	25%	0.7	--	--	--
	129	1.0	25%	0.8	--	--	--
	Other	12.7	25%	9.7	5	25%	4
	Subtotal	19.4	--	14.8	14	25%	11
All		83.6	--	47.9	232	--	143

[A] Iron Ore Handling

TABLE 8-4

PM$_{10}$ SOURCE CONTRIBUTIONS TO THE ANNUAL AND 24-HOUR AVERAGE DESIGN CONCENTRATIONS, AND PROPOSED CONTROL STRATEGIES FOR THE LOWER SOUTHERN HOT SPOT RECEPTOR

		CDM 2.0 5-Year Average			RAM Sixth-Highest 24-Hour Average		
Source Types	Source Numbers	Calibrated Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)	Uncontrolled Contributions ($\mu g/m^3$)	Proposed Controls	Controlled Contributions ($\mu g/m^3$)
Background	--	25	--	25	68	--	68
Point	28[A]	2.0	96%	.1	--	--	--
	29[A]	1.2	96%	<.1	--	--	--
	30[A]	1.7	96%	.1	--	--	--
	32[A]	.9	96%	<.1	--	--	--
	33[A]	2.8	96%	.1	--	--	--
	41[B]	.9	96%	<.1	--	--	--
	42[B]	5.3	96%	.2	56	96%	2
	43[B]	4.6	96%	.2	36	96%	1
	44[B]	2.5	96%	.1	41	96%	2
	45[B]	2.5	96%	.1	41	96%	2
	46[B]	2.2	96%	.1	--	--	--
	48[B]	8.5	96%	.3	145	96%	6
	49[B]	8.0	96%	.3	127	96%	5
	50[B]	1.1	96%	<.1	--	--	--
	Other	6.9	None	6.9	19	None	19
	Subtotal	51.1	--	8.9	465	--	37
Area	95	3.4	25%	2.9	--	--	--
	112	2.3	25%	1.7	12	25%	9
	129	.7	25%	.5	4	25%	3
	Other	12.7	25%	9.5	37	25%	28
	Subtotal	19.1	25%	14.6	53	25%	40
All		95.2	--	48.5	586	--	145

[A] Chemical Mfg. - Pigments
[B] Antimony Smelting - Fire Retardant Mfg.

characteristics of this area source were identified. These unusual characteristics are discussed below.

The three distinguishing features of area source 145 are:

1) The center hot spot and monitoring site 4 are contained within the area source. Site 4 was the site where the greatest overpredictions of measured concentrations were obtained in the model evaluation analyses.

2) The emission rate for this area source was a factor of two greater than the next largest area source in the inventory. A high level of construction activity associated with this area source was responsible for the elevated emission rate.

3) The emission release height modeled for this source was found to be too low for the types of emissions in this area source.

Upon further investigation, the construction activity emission rate was found to be in error and was corrected. In addition, an appropriate value was inserted for the release height. These changes together with a 25 percent emission reduction for this area source provided the necessary 60 percent impact reduction at the center hot spot due to area source 145.

Table 8-3 shows that an iron ore handling facility and nearby area sources are the primary contributors to concentrations in excess of the NAAQS at the upper southern hot spot receptor and that the required emission limits are those associated with the annual standard. The proposed control strategy includes emission reductions of 96 percent for the iron ore facility and 25 percent for area sources.

Table 8-4 shows that the three source types primarily responsible for concentrations in excess of the NAAQS at the lower southern hot spot receptor are a chemical manufacturing plant, an antimony smelting and fire retardant manufacturing facility and nearby area sources. For this receptor, the 24-hour and annual standards require the same levels of emission controls. Specifically, emission reductions of 96 percent for the chemical plant and antimony facility are proposed together with 25 percent reductions for area source emissions.

8.7 Control Strategy Testing

To provide an efficient mechanism for testing the above set of control strategies, the following plan was developed. The control strategy testing modeling was performed using an "impact offset" approach in which the sources with proposed controls were modeled in two configurations simultaneously. In the first configuration, the sources under consideration were modeled with negative emissions to reflect uncontrolled conditions, and in the second configuration these sources were modeled with positive emissions to reflect proposed control conditions. The modeling results thus provided the net negative change in impacts produced by the emission controls. These negative impacts were then summed with the uncontrolled impacts calculated previously for all sources.

The CDM 2.0 and RAM dispersion models were used to estimate PM_{10} concentrations at all the receptors in the area in excess of the NAAQS shown in Figure 8-4. All five years of meteorological data (1980 to 1984) were used in this modeling. When the results of the RAM and CDM 2.0 modeling showed continued nonattainment at the hot spot receptors, further control measures were developed. The RAM and CDM 2.0 modeling was repeated until compliance with the 24-hour and annual average PM_{10} NAAQS was achieved at all the previously identified receptors in excess of the NAAQS.

9.0 INDUSTRIAL SOURCE EXAMPLE

9.1 Introduction

This section describes an example SIP development process for a monitoring site located within an industrial area. Measurements at this site clearly demonstrate exceedances of the 24-hour and annual average PM_{10} NAAQS. However, the causes of the elevated concentrations of PM_{10} and the corresponding control strategy are not as evident. Based strictly on the emission inventory, a large steel mill and traffic-generated resuspended road dust appear to be potentially large contributors to observed PM_{10} concentrations. However, the level of confidence associated with emission inventory-supplied source contribution estimates is insufficient for reliable control strategy development. Therefore, an investigation, which included data collection and modeling efforts, was conducted in order to apportion the source impacts with the level of confidence necessary for making control strategy decisions.

The industrial site PM_{10} SIP development example presented in this section was compiled primarily from experience gained from working on an individual site. The location of the site is unimportant to the objective of the example and is therefore not identified. In addition, the data base used for this example was modified to better illustrate the SIP development process.

9.1.1 Overview of the Source Apportionment Study

A combined receptor and dispersion modeling study was implemented with the objective of identifying and quantifying the impacts of the sources which contributed to the violations of the PM_{10} NAAQS recorded at the monitoring site. To supplement the emission inventory in providing a basis for completing the data gathering efforts, pollution concentration roses were prepared using the two most recent years of data for the eight TSP monitoring sites located near the PM_{10} monitoring station. The pollution roses indicated that the major sources of TSP were located in the quadrant south of the PM_{10} monitor. This suggested that additional emphasis should be placed on characterizing steel mill related contributions because the steel mill is the largest source of particulate emissions located nearby and south of the monitoring site (see Figure 9-1).

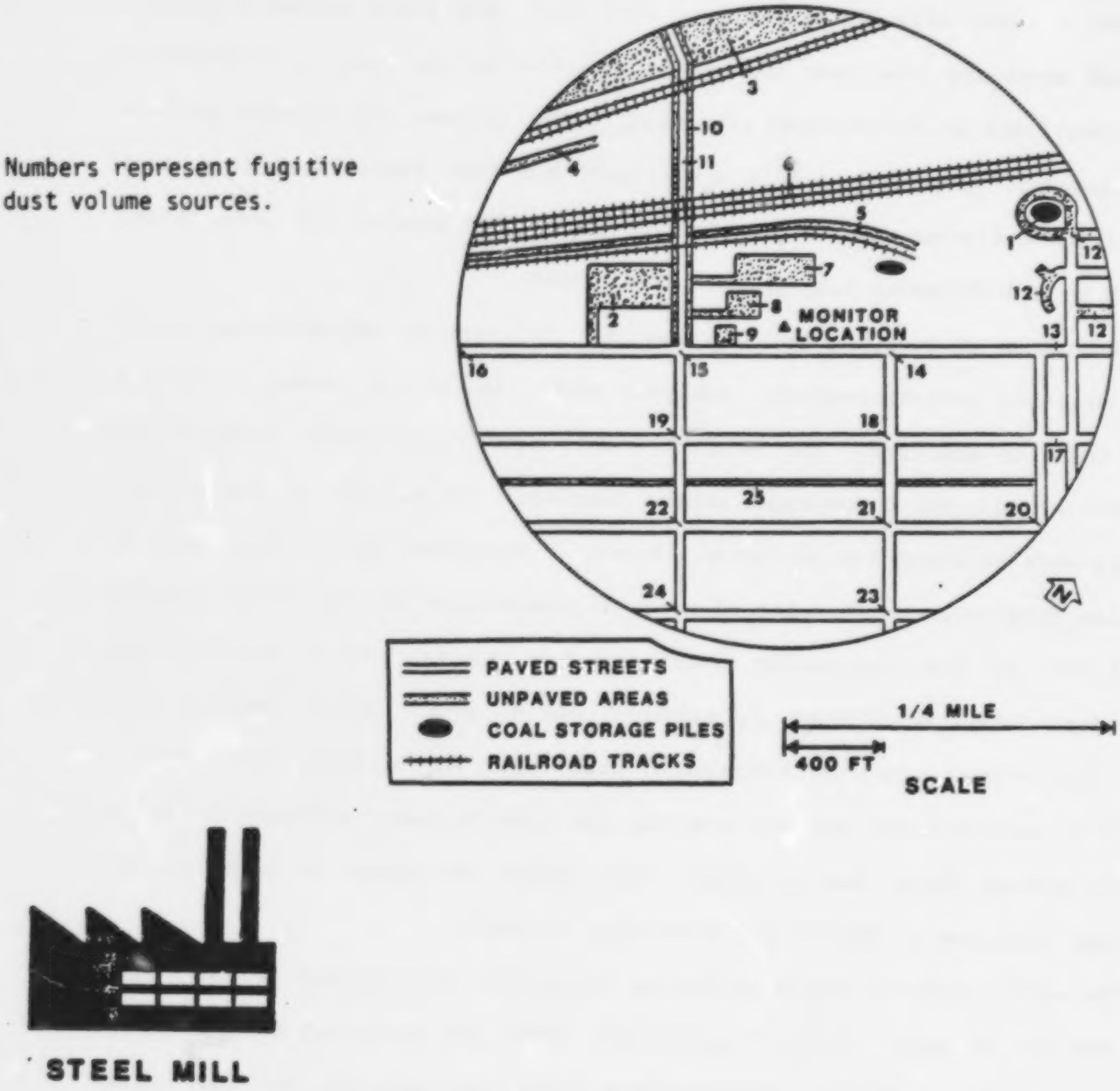
9.1.2 Data Collection Tasks

This section describes the data gathering tasks which were conducted in order to satisfy the input requirements of the receptor and dispersion models. The starting point of the data gathering effort was reviewing the available data which consisted primarily of: 1) ambient PM_{10} samples collected for one-year on an every sixth day schedule using quartz fiber filters and a SSHV sampler; and 2) hourly measurements of wind direction, wind speed and temperature at the PM_{10} monitoring station. In addition, for one-month a dichotomous sampler was in operation at the monitoring site and collected several 24-hour coarse and fine fraction samples on Teflon filters. The results of the PM_{10} monitoring program provided an annual average PM_{10} concentration of 65 $\mu g/m^3$ as well as six exceedances of the 24-hour average PM_{10} standard of 150 $\mu g/m^3$.

The initial data collection effort performed for this investigation was a site visit to compile a microinventory and obtain bulk samples from local emission sources. The results of the microinventory were combined with published emission factors to calculate emission rates for input to a dispersion model.

As part of the site visit, bulk samples of material were collected from six sources in the general vicinity of the site which had been identified as

Numbers represent fugitive dust volume sources.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24
25
MONITOR LOCATION
N
PAVED STREETS
UNPAVED AREAS
COAL STORAGE PILES
RAILROAD TRACKS
1/4 MILE
400 FT
SCALE
STEEL MILL

Figure 9-1. Schematic Diagram of the Industrial Source Example Study Area.

potentially important contributors to PM_{10}. The sources which were sampled included: a steel mill (blast furnace, coke oven, and basic oxygen furnace); two road shoulders (one near the monitoring site and one near an inoperative lead plant); and an agricultural processing plant (potash, corn gluten pellets and soybeans). For each sample an aliquot was then aerosolized in a dust chamber and collected onto a quartz filter by a SSHV sampler and onto Teflon filters by a dichotomous sampler (U.S. EPA, 1984b).

Application of receptor modeling required the chemical characterization of the source and ambient samples. Analysis costs limited the number of filters which could be analyzed. The receptor model input requirements mandated the analysis of all the resuspended source samples. Two subsets of the ambient filters were selected for analysis. Subset A contained the filters from 20 sampling days which were selected to be representative of the annual average conditions at the monitoring station. The average PM_{10} concentration calculated from the filters in subset A was 67 $\mu g/m^3$, which compares well with the annual average calculated from all the filters (65 $\mu g/m^3$). Subset B contained the samples from the six days on which exceedances of the 24-hour average NAAQS were recorded. This subset was chosen to guide control strategy development related to the 24-hour standard.

Two multi-elemental characterization techniques were applied to the source and ambient filters. X-ray fluorescence (XRF) was performed on the Teflon filters and Plasma Emission Spectroscopy (PES) was employed for the quartz filters. The elemental carbon content of the samples was determined by optical attenuation. In addition to the chemical characterization procedures, optical microscopy was applied to several of the ambient samples. Optical microscopy, which provides reliable particle identifications and semi-quantitative source contribution estimates, was used as a QA check on the receptor modeling source identifications and to aid in the receptor/dispersion model reconciliation process.

9.2 Data Preparation

9.2.1 Dispersion Modeling Data Preparation

The inventory of all the point sources in the two counties surrounding the PM_{10} monitoring site was obtained from the State agency responsible for local air pollution control regulations. A total of 882 point sources were included in the inventory. In order to reduce the point source inventory to a more manageable size, the following set of emission-size versus distance from the receptor criteria were developed:

Distance (Kilometers)	Emission Rate (grams/second)
<5.0	>0.01
5.0<10.0	>0.1
10.0<20.0	>1.0
>20.0	>3.0

Application of the above criteria on a composite plant basis resulted in an inventory of 140 point sources for input to the dispersion model. The point source inventory was modified for use in modeling PM_{10} impacts by applying source specific PM_{10}/TSP emission ratios to the TSP emission factors which were originally contained in the inventory.

The State inventory did not contain area or fugitive dust sources. As a partial solution for this deficiency, the fugitive dust sources compiled in the microinventory were included as volume sources in the input to the dispersion model. Emission rates for the fugitive dust sources were estimated with respect to PM_{10} emissions (see U.S. EPA, 1985a and 1986c).

The hourly wind direction, wind speed, and temperature measurements collected on-site were used directly for model input. Also required for dispersion modeling were Pasquill/Turner atmospheric stability data and mixing height estimates. The calculations to obtain the stability data used for model input were performed with the CRSTER preprocessor program using the on-site wind speed measurements in combination with ceiling and cloud cover data obtained from the nearby NWS station as well as the latitude and longitude of the PM_{10} monitoring site. Mixing heights were calculated by applying the CRSTER preprocessor to NWS data from the nearest surface and upper air stations.

For this study, background concentrations were defined as that portion of the measured ambient levels that is not attributable to emissions within the study area. To estimate the appropriate background concentrations, a pollution rose was developed using data from TSP monitoring stations located outside the study area. Data were used only from the days having persistent winds blowing into the study area from the direction of the background TSP stations. An annual average TSP concentration of 26 $\mu g/m^3$ can be attributed to sources outside the study area. Application of the site-specific PM_{10}/TSP ratio (0.57) yields an annual average background PM_{10} concentration of 15 $\mu g/m^3$. In addition to the annual average, background concentrations were also estimated as a function of wind direction for use in the 24-hour average modeling.

9.2.2 Receptor Modeling Data Preparation

Receptor modeling was performed for this study using the Chemical Mass Balance (CMB) model (U.S. EPA, 1987c). The CMB model requires an input file containing the measured ambient concentrations of the elements for which the samples were analyzed. This requirement was fulfilled by transforming the results of the ambient filter analyses into the format specified by the CMB model. In addition, the CMB model requires a file containing the source compositions reported as the elemental mass fractions. A source composition file in CMB specified format was compiled. The file contained the elemental composition of the resuspended local sources as well as a number of source profiles which were extracted from EPA's Source Composition Library (U.S. EPA, 1984a).

9.3 Model Evaluation Analyses

9.3.1 Dispersion Modeling Procedure

The Industrial Source Complex Short-Term (ISCST) model (U.S. EPA, 1986d) was used for this investigation. ISCST was used because it is applicable to industrial sources and it contains several features that provide increased efficiency to the source apportionment process. Two of the features of ISCST which proved to be advantageous were its ability to: 1) model the microinventoried fugitive dust sources as volume sources; and 2) calculate the combined impact for selected groups of sources. This latter feature greatly decreased the manipulations which were necessary to transform the dispersion and receptor modeling results into a format which provided a logical basis for comparisons. Values for the user-selectable parameters of ISCST were determined in accordance with standard regulatory practice (Guideline on Air Quality Models (Revised), (U.S. EPA, 1986b).

The emission inventory was used to develop a tabulation of the types of materials emitted by each source. The many types of emitted materials were then associated with one of twenty general categories because ISCST is limited to predicting impacts for a total of twenty source groups. Each of the 140 point sources and 25 volume sources was assigned a code corresponding to one of the twenty categories.

9.3.2 Receptor Modeling Procedure

Two receptor oriented approaches were applied for this study: the CMB model and the optical microscopy technique. CMB modeling analyses were performed on the filters contained in subsets A and B described in Section 9.1.2. The modeling procedure consisted of obtaining a "best" fit solution by systematically adding and removing sources and elements from the mass balance calculation in accordance with the Protocol for Applying and Validating the CMB Model (U.S. EPA, 1987d). Termination of the iterative fitting process at the "best" fit solution was determined on the basis of a series of summary statistics reported by the model as well as the analyst's understanding of the airshed.

Two SSHV samples, two coarse fraction dichotomous samples and one fine fraction dichotomous sample underwent optical microscopic analysis to confirm the CMB source identifications. In addition, the results of the particle counting performed as part of the microscopic analysis were used to calculate semi-quantitative source contribution estimates.

9.3.3 Comparison of Receptor and Dispersion Model Results

The source contribution estimates provided by the CMB and ISCST models for subset A (annual average) and subset B (samples violating the 24-hour NAAQS) are compared in Table 9-1. The results of the two models display reasonable agreement in two categories: 1) the background estimates used by ISCST are approximately equal to the secondary sulfate values estimated by CMB; and 2) resuspended road dust is listed as a major source of PM_{10} by both methods. In addition, the similarities and differences between CMB and ISCST are consistent between subsets A and B. Aside from the relatively few similarities which have been enumerated, many differences between the CMB and ISCST results are evident. These differences were examined and then

TABLE 9-1

COMPARISON OF INITIAL EVALUATION RESULTS BY ISCST AND CMB FOR SUBSETS A AND B ($\mu g/m^3$).

	Subset A		Subset B	
Source Categories	ISCST	CMB	ISCST	CMB
Oil & Gas Combustion	1.6	---	2.0	---
Wood-fired Boilers	0.2	3.2	0.8	5.6
Coal Combustion	0.6	2.8	1.2	8.0
Coking Operations	1.4	8.6	4.0	23.2
Blast Furnace	0.6	12.0	2.0	3.6
Basic Oxygen Furnace		3.8		10.4
Coal Handling	0.3	---	0.6	---
Agricultural Prod. Handling	1.1	---	1.6	---
Paint Production	---	---	0.8	---
Cement & Limestone	1.9	---	1.9	---
Sand & Bentonite	1.2	---	1.7	---
Aluminum Production	---	---	0.4	---
Zinc Processing	0.8	---	0.6	---
Oil Refining	0.6	---	1.6	---
Fertilizer	---	---	0.8	---
Tire Production	---	---	2.2	---
Motor Vehicle Exhaust	15.1	2.4	34.8	2.4
Road Dust & Soil		30.0		79.2
Secondary $(NH_4)_2SO_4$	---	15.0	---	27.4
Background	15.0	---	32.0	---
Total	45.4	77.8	89.0	189.8
Measured	67.0	67.0	162.0	162.0

reconciled following the eight step procedure described in the Protocol for Reconciling Differences Among Receptor and Dispersion Models (U.S. EPA, 1987b). In the following Section, the differences between the CMB and ISCST source contribution estimates will be identified and their reconciliation summarized on a case by case basis. A more detailed description of the example can be found in the aforementioned protocol (U.S. EPA, 1987b).

9.3.4 Reconciliation of CMB and ISCST Results

Case 1: A significant disagreement exists between the CMB and ISCST estimates of the coal combustion impacts. What is the cause of this disagreement and how can the difference be reconciled?

The first step taken in reconciling the coal combustion impact estimates was to review the ambient and source composition data for errors which could potentially invalidate the CMB results. This review uncovered no obvious errors in the CMB input data related to coal combustion. The next step was to examine the comparisons between OM, CMB and ISCST which are shown in Tables 9-2 and 9-3. These tables show that OM predicts coal combustion impacts in reasonable agreement with CMB and larger than ISCST. The emission inventory was then reviewed with respect to coal combustion sources. The review identified four major coal combustion facilities. For the closest of these sources to the receptor, the emission inventory contained an erroneously high value for the efficiency of the emission controls. A correct value was obtained and ISCST was then re-run with the corrected inventory providing much closer agreement between CMB and ISCST with respect to coal combustion impacts.

Case 2: The combined contributions of motor vehicle exhaust and resuspended road dust, as estimated by CMB and ISCST, disagree by over a factor of two. What is the cause of the disagreement and how can the difference be reconciled?

TABLE 9-2

COMPARISON OF THE RECEPTOR AND DISPERSION MODEL RESULTS FOR THE OCTOBER 1, 1983 PM_{10} SAMPLES

Dispersion Modeling Source Groups	Optical Microscopy Source Categories	CMB Modeling Source Types	Modeled Concentrations ($\mu g/m^3$)						
			Dispersion Modeled Impacts	SSHV Optical Micros. (A)	Coarse Dichot Optical Micros. (B)	Fine Dichot by Diff. (A-B)	SSHV CMB	Fine Dichot CMB	Coarse Dichot CMB
Oil & Gas Combustion	Fuel Comb., Carbon	----	5.8	-.-	1.0	1.0	-.-	-.-	-.-
Wood Combustion	----	Wood Boiler	1.4	-.-	-.-	-.-	-.-	8.6	3.0
Coal Combustion	Fuel Comb.,Part.Pyr.Coal	Coal-fired Power Plant	0.8	8.6	3.8	4.8	2.0	-.-	6.6
----	St.Mill, Part. Pyr. Coal	----	-.-	5.8	0.4	5.4	-.-	-.-	-.-
Coke	Steel Mill, Coke	Coke Ash	0.4	7.0	4.4	2.6	12.4	39.6	-.-
Steel	Steel Mill	Blast Furnace	2.0	34.6	12.4	22.2	16.4	-.-	-.-
----	----	Basic Oxygen Furnace	-.-	-.-	-.-	-.-	5.6	13.2	8.4
Coal	Coal Handling	----	0.8	4.6	2.8	1.8	-.-	-.-	-.-
Agricultural Products	Agr. Prod. Handling	----	5.4	6.0	-.-	6.0	-.-	-.-	-.-
Paint Products	Spray Painting	----	1.2	-.-	-.-	-.-	-.-	-.-	-.-
Cement, Limestone	Cement Handling	----	2.0	-.-	-.-	-.-	-.-	-.-	-.-
Lead	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Sand, Bentonite	Clay Handling	----	-.-	-.-	1.4	1.4	-.-	-.-	-.-
Aluminum	Alumina Handling	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Zinc	----	----	2.6	-.-	-.-	-.-	-.-	-.-	-.-
Misc. Chemicals	----	----	4.4	-.-	-.-	-.-	-.-	-.-	-.-
Refinery Catalysts	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Misc. Refinery	Oil Refining	----	3.2	-.-	-.-	-.-	-.-	-.-	-.-
Fertilizer	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Tire Products	----	----	8.6	-.-	-.-	-.-	-.-	-.-	-.-
----	Traffic, Tire Fragments	----	-.-	3.2	2.2	1.0	-.-	-.-	-.-
----	Traffic, <1um Carbon	Automobile Exhaust	-.-	5.0	2.8	2.2	4.4	1.0	0.8
Road Dust	Traffic, Wind Erosion	Near Street 1	32.2	41.2	17.4	23.8	25.2	2.0	75.2
----	Biologicals & Misc.	----	-.-	-.-	5.2	5.2	-.-	-.-	-.-
----	Secondary Aerosols	Secondary $(NH_4)_2SO_4$	-.-	27.6	5.3	22.3	27.5	24.4	3.0
Background	----	----	31.0	-.-	-.-	-.-	-.-	-.-	-.-
Total	----	----	101.8	143.6	59.1	99.7	93.5	88.8	97.1
Measured $PM_{2.5}$	----	----	99.8	-.-	-.-	99.8	-.-	99.8	-.-
Measured $PM_{2.5-10}$	----	----	65.4	-.-	65.4	-.-	-.-	-.-	65.4
Measured Dichot. PM_{10}	----	----	165.2	-.-	-.-	-.-	-.-	-.-	-.-
Measured SSHV PM_{10}	----	----	163.2	163.2	-.-	-.-	163.2	-.-	-.-

TABLE 9-3

COMPARISON OF THE RECEPTOR AND DISPERSION MODEL RESULTS FOR THE OCTOBER 25, 1983 PM_{10} SAMPLES

			Modeled Concentrations (µg/m^3)						
			Dispersion Modeled Impacts	Optical Microscopy			SSHV CMB	Fine Dichot CMB	Coarse Dichot CMB
Dispersion Modeling Source Groups	Optical Microscopy Source Categories	CMB Modeling Source Types		SSHV	Fine Dichot	Coarse Dichot			
Oil & Gas Combustion	Fuel Comb., Carbon	----	0.4	-.-	1.0	0.4	-.-	-.-	-.-
Wood Combustion	----	Wood Boiler	-.-	-.-	-.-	-.-	-.-	6.8	0.6
Coal Combustion	Fuel Comb.,Part.Pyr.Coal	Coal-fired Power Plant	-.-	1.8	1.8	1.2	-.-	-.-	-.-
----	St.Mill, Part. Pyr. Coal	----	-.-	2.4	0.6	0.1	-.-	-.-	-.-
Coke	Steel Mill, Coke	Coke Ash	-.-	3.0	2.8	1.6	11.8	-.-	-.-
Steel	Steel Mill	Blast Furnace	-.-	5.4	5.8	1.0	10.6	-.-	5.0
----	----	Basic Oxygen Furnace	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Coal	Coal Handling	----	-.-	3.0	2.2	1.0	-.-	-.-	-.-
Agricultural Product	Agr. Prod. Handling	----	1.0	3.4	2.6	2.6	-.-	-.-	-.-
Paint Products	Spray Painting	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Cement, Limestone	Cement Handling	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Lead	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Sand, Bentonite	Clay Handling	----	0.6	-.-	-.-	-.-	-.-	-.-	-.-
Aluminum	Alumina Processing	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Zinc	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Misc. Chemicals	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Refinery Catalysts	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Misc. Refinery	Oil Refining	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Fertilizer	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
Tire Products	----	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
----	Traffic, Tire Fragments	----	-.-	1.2	1.0	0.6	-.-	-.-	-.-
----	Traffic, <1um Carbon	Automobile Exhaust	-.-	2.4	1.2	1.6	2.8	4.6	2.0
Road Dust	Traffic, Wind Erosion	Near Street 1	41.2	40.2	10.2	5.4	7.4	-.-	20.6
----	Biologicals & Misc.	----	-.-	-.-	-.-	-.-	-.-	-.-	-.-
----	Secondary Aerosols	Secondary $(NH_4)_2SO_4$	-.-	8.0	1.0	4.4	5.4	4.4	0.8
Background	----	----	17.0	-.-	-.-	-.-	-.-	-.-	-.-
Total	----	----	60.2	70.8	30.2	19.9	38.1	15.8	29.6
Measured $PM_{2.5}$	----	----	19.9	-.-	-.-	19.9	-.-	19.9	-.-
Measured $PM_{2.5-10}$	----	----	30.2	-.-	30.2	-.-	-.-	-.-	30.2
Measured Dichot. PM_{10}	----	----	50.1	-.-	-.-	-.-	-.-	-.-	-.-
Measured SSHV PM_{10}	----	----	70.8	70.8	-.-	-.-	70.8	-.-	-.-

The first step taken to reconcile the disagreement between CMB and ISCST with respect to the combined impact of vehicle exhaust and road dust was to re-examine the comparisons between OM, CMB and ISCST. In this case, OM was found to agree very well with ISCST. The CMB input data were then evaluated for potential errors related to estimating road dust and vehicle exhaust. The coarse fraction filter on which the resuspended road dust source sample was collected appeared to have lost a substantial fraction of the sample between the time it was weighed and the time it was analyzed. This potential problem was identified by performing the following test: 1) convert the mass fractions of the major elements to mass fractions of those elements as their assumed oxides (i.e., convert mass fraction of Si to mass fraction of SiO_2); 2) sum the mass fractions of the major species reported as oxides; 3) compare the sum of the mass fractions with a value of one. The carbon content of the road dust was known to be approximately five percent. Therefore, the sum of the oxides of the major species would be expected to equal approximately 0.9. When this test was performed on the results of the analysis of the coarse fraction road dust sample, the sum of the mass fractions of the oxides was approximately 0.45. This indicated that the mass of the filter was high by a factor of two. The filter was then re-weighed and the gross filter mass was found to be lower than the measurement which was made immediately after resuspension. The probable cause of the difference was the loss of particles from the overloaded coarse fraction filter. The mass determined during the re-weighing was used to revise the road dust source composition profile. The revised mass fractions were higher than the original mass fractions and would therefore decrease the CMB estimated road dust impacts.

The CMB model was re-run with the revised road dust profile and good agreement was now found between CMB and ISCST with respect to the combined impacts of road dust and vehicle exhaust. The CMB estimated impacts of the other sources remained unchanged by the revised road dust profile. Finally, the other source samples were re-weighed and no other cases of significant mass loss were identified.

Case 3: CMB estimates wood-fired boilers are a much larger contributor to PM_{10} than does ISCST. What is the cause of the disagreement and how can the difference be reconciled?

The first step in reconciling the CMB and ISCST estimates for the wood-fired boiler impacts was to review the CMB input data. The review did not identify any obvious errors in the data. Next, the OM results were examined. In this case, OM was of little assistance because OM did not identify any impact from wood-fired boilers while CMB and ISCST both did. The emission inventory was then evaluated in terms of wood-fired boilers and revealed that an erroneous emission rate was listed in the inventory for one of the wood-fired boilers. Therefore the inventory was revised. ISCST was then re-run and good agreement was found between CMB and ISCST with respect to the wood-fired boiler source category.

Case 4: There is a big disagreement between CMB and ISCST for steel mill related impacts (i.e., coking operations, blast furnace and basic oxygen furnace source categories). What are the causes for the disagreements and how can the differences be reconciled?

The steel mill source is of additional interest due to the fact that there is a big disagreement between CMB and ISCST for each of the three main PM_{10} emitting activities within the steel mill. This disagreement results in CMB predicting that the steel mill is the largest industrial source of the PM_{10} levels observed at the receptor site while ISCST predicts that the steel mill is a relatively minor source. This discrepancy will have a big impact on control strategy development and therefore must be reconciled very conclusively.

The first step in the reconciliation process was to review the CMB input data. The review did not identify any obvious anomalies in the CMB input data. In fact, the steel mill related source profiles were judged to be of very good quality due to the close agreement which was found between the PES analysis of the resuspended samples which were collected on quartz fiber and the XRF analysis of those collected on Teflon. The next step was to examine the impacts estimated by OM for the steel mill. In this case, OM was found to agree much better with CMB than with ISCST. The emission inventory was then reviewed with respect to steel mill emissions. The stack emission rates were found to be in good agreement with emission rates for similar activities at other steel mills. However, the review revealed that the emission inventory did not contain any emission factors associated with fugitive emissions from the steel plant. This omission was viewed as a potentially serious deficiency and therefore a site visit was conducted to re-assess the fugitive emission rates at the steel mill. Substantial fugitive emissions were found to be associated with the coking operations, blast furnace and basic oxygen furnace. ISCST was then re-run with the new fugitive emissions for the steel plant included in the inventory. This resulted in very good agreement between CMB and ISCST with respect to the steel mill contribution.

9.3.5 Post-Reconciliation Comparison of CMB and ISCST Results

The previous section presented the reconciliation of the CMB and ISCST source impact estimates and resulted in a number of revisions to the input data used by the models. Following reconciliation, CMB and ISCST were re-run for subsets A and B using the revised data. Very good agreement now exists between the source impacts estimated by CMB and ISCST for subsets A and B. ISCST was then run using five years of meteorological data to obtain estimates of the annual average PM_{10} and the six highest values. The results provided by ISCST are shown in Table 9-4. ISCST predicts that both the annual average and 24-hour PM_{10} NAAQS will be exceeded at the monitoring station. Steel mill related activities are the major contributors to PM_{10} at the receptor site. The second largest contributor is resuspended road dust. The six highest predicted PM_{10} concentrations all occur during persistent south winds. The next section will discuss the development of control strategies to bring the receptor site into attainment of the PM_{10} NAAQS.

9.4 Control Strategy Development

The first step in control strategy development was determining the annual and 24-hour average PM_{10} design concentrations for the monitoring station that must be reduced to the level of the appropriate NAAQS. For this study, the annual average design concentration was calculated as the mean of the PM_{10} concentrations recorded during the one-year PM_{10} sampling program (65 $\mu g/m^3$). To determine the 24-hour average design concentration, the table look-up procedure (U.S. EPA, 1987a) was used in combination with the results of the five years of ISCST simulations. This approach required the use of the sixth highest modeled PM_{10} value exceeding the 24-hour NAAQS to be used as the design concentration. Table 9-4 shows the 24-hour average design concentration (183 $\mu g/m^3$) and gives the corresponding source contributions.

After establishing the design concentrations, emission limits must be set on the basis of the NAAQS (annual or 24-hour average) which requires the most stringent set of controls. For this study, the total reductions in PM_{10} concentrations required to attain the annual and 24-hour average NAAQS were 23 percent and 18 percent, respectively. Table 9-4 indicates that the relative contributions of the major sources are similar for the annual average and 24-hour average design concentrations. This suggests that adoption of a set of emission limits designed to attain the annual standard should in turn bring

TABLE 9-4

SOURCE CONTRIBUTIONS ESTIMATED BY ISCST USING 5 YEARS OF METEOROLOGICAL DATA. ($\mu g/m^3$)

Source Categories	Annual Average	Sixth-Highest 24-hr Avg. Concentration
Oil & Gas Combustion	1.4	1.7
Wood-fired Boilers	3.0	6.0
Coal Combustion	2.0	7.5
Coking Operations	8.7	27.6
Blast Furnace	10.1	38.0
Basic Oxygen Furnace	2.7	14.8
Coal Handling	0.3	0.4
Agricultural Prod. Handling	0.9	0.4
Paint Production	0.1	1.1
Cement & Limestone	1.6	2.1
Sand & Bentonite	1.0	0.7
Aluminum Production	0.1	0.2
Zinc Processing	0.6	0.6
Oil Refining	0.3	2.1
Fertilizer	0.1	0.9
Tire Production	0.4	1.5
Motor Vehicle Exhaust Road Dust & Soil	12.7	45.4
Background	15.0	32.0
Total	61.0	183.0

the monitoring station into compliance with the 24-hour standard. To ensure that this was the case, emission limits were developed to attain the annual standard and then were evaluated with respect to the annual and 24-hour standards.

The total reduction (TR) to achieve the annual standard is given by:

$$TR\ (\mu g/m^3) = PM_{10}\ \text{Design Concentration} - PM_{10}\ \text{NAAQS}$$

which for this example leads to:

$$TR = 65 - 50 = 15\ \mu g/m^3.$$

From Table 9-4, on an annual average basis the contributions of the major sources to PM_{10} are seen to be:

Source	Contribution to PM_{10}
Wood-fired Boilers	3.0 $\mu g/m^3$
Coal Combustion	2.0 $\mu g/m^3$
Coking Operations	8.7 $\mu g/m^3$
Blast Furnace	10.1 $\mu g/m^3$
B.O.F.	2.7 $\mu g/m^3$
Road & Soil Dust & Veh. Exhaust	12.7 $\mu g/m^3$

On the basis of available technology, cost-effectiveness and enforcability, the following set of reductions in source contributions were derived:

Source	Individual Source Reduction
Wood-fired Boilers	1.0 $\mu g/m^3$
Coking Operations	5.0 $\mu g/m^3$
Blast Furnace	6.0 $\mu g/m^3$
B.O.F.	1.0 $\mu g/m^3$
Road & Soil Dust & Veh. Exhaust	2.0 $\mu g/m^3$
	TR = 15.0 $\mu g/m^3$

The percent emission reductions corresponding to the above list of absolute source reductions are:

Source	Percent Emission Reduction
Wood-fired Boilers	33%
Coking Operations	57%
Blast Furnace	59%
B.O.F.	37%
Road & Soil Dust & Veh. Exhaust	16%

The total reduction to achieve the 24-hour NAAQS is:

TR = 183 - 150 = 33 $\mu g/m^3$.

From Table 9-4, the contributions of the major sources to the PM_{10} concentration on the sixth highest modeled day are:

Source	Contribution to PM_{10}
Wood-fired Boilers	6.0 $\mu g/m^3$
Coal Combustion	7.5 $\mu g/m^3$
Coking Operations	27.6 $\mu g/m^3$
Blast Furnace	38.0 $\mu g/m^3$
B.O.F.	14.8 $\mu g/m^3$
Road & Soil Dust & Veh. Exhaust	45.4 $\mu g/m^3$

Application of the percent emission reductions derived to attain the annual standard to the sixth highest day contributions provides the following individual source reductions:

Source	Individual Source Reductions
Wood-fired Boilers	2.0 $\mu g/m^3$
Coking Operations	15.7 $\mu g/m^3$
Blast Furnace	22.4 $\mu g/m^3$
B.O.F.	5.5 $\mu g/m^3$
Road & Soil Dust & Veh. Exhaust	7.2 $\mu g/m^3$
	TR = 52.8 $\mu g/m^3$

This demonstrates that the emission limits which were derived for the annual average case should also ensure the attainment of the 24-hour NAAQS. The next section will describe the testing of the proposed control strategy with respect to the annual and 24-hour NAAQS.

9.5 Control Strategy Testing

To test the control strategy, the proposed emission reductions were applied to the emission inventory and the ISCST model was re-run with five years of meteorological data. The average of the five predicted annual averages was 49.6 $\mu g/m^3$ and only two exceedances of the 24-hour NAAQS were predicted for the five year period. The control strategy was therefore sufficient to achieve the attainment of the annual and 24-hour average PM_{10} NAAQS.

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